THE

GEOLOGICAL MAGAZINE

NEW SERIES. DECADE VI. VOL. II.

No. XII.—DECEMBER, 1915.

ORIGINAL ARTICLES.

I.—The Danbury Gravels.

By Professor J. W. Gregory, D.Sc., F.R.S.

DANBURY stands on a gravel-capped plateau in Mid-Essex, five miles east of Chelmsford. The gravel is part of a once larger sheet and contains a variety of rocks foreign to the district. It was therefore naturally at first regarded as a glacial gravel. This view was adopted by S. V. Wood, jun. (e.g. 1867, p. 12; 1870, p. 61), by the Rev. O. Fisher (1868, p. 98), on the Geological Survey Map (Sheet 1, N.E., 1871), and by Mr. Whitaker (1889, p. 279). Sir Joseph Prestwich regarded the Danbury gravels (1890, p. 135) as Bagshot pebble-beds invaded by some glacial agent, and the late H. B. Woodward (1903, p. 15) described them as the wreck in Glacial times of an older gravel.

Objection has, however, been often taken to the glacial origin of these gravels, as by French (1891, p. 211). They lack the structural features and constituents which in this district are characteristic of glacial deposits. In recent years the conclusion has been widely adopted that these gravels are fluviatile in origin and pre-Glacial in age.

The Danbury gravels lie on a plateau of London Clay at the level of from 300 to 360 feet O.D. They are in situ upon the surface of the plateau at Danbury and on the ridge going north to Little Baddow. They are there exposed in occasional natural outcrops, and in gravel-pits to the south of Danbury Church and to the east of the road to Little Baddow, about a mile north of Danbury Church. Redeposited Danbury gravels occur on the slopes of the Danbury hills; and at still lower levels they are mixed with material from the glacial beds.

The most striking feature of the Danbury gravel is its high proportion of quartzites which are foreign to the district. These quartzites include the liver-coloured saccharoidal variety, pink, yellow, white, and black quartzites, varieties seamed with secondary quartz-veins, some brecciated quartzites, and some which are merely quartzitic sandstones. The series also includes jasperoids which pass into compact red siliceous shales and black cherts.

One of the rarest rocks found in the Danbury gravel is chert from the Lower Greensand, though it is so abundant in the lower level gravels of South-Eastern Essex. Prestwich recorded chert at Danbury (1890, p. 135), and he generally used that term for the Lower Greensand chert; he remarked, however, that it is more abundant in the

lower level gravels. Dr. Salter does not record this chert from Danbury, but he has lent me a small pebble he collected from the pit to the south of Danbury, and a section shows that it is a Lower Greensand chert, an identification kindly confirmed by Dr. Hinde. I obtained a larger specimen (2½ by 2 by 1 inch) from a pit a mile north of Danbury. The Lower Greensand chert is, however, extremely rare in these gravels, whereas in the lower level gravels of Southminster and Southend it forms from 6–14 per cent of the pebbles.

The Danbury gravels have so far yielded none of the felsites or 'rhyolites', which are found in the neighbouring lower level gravels, as I have found them at Gay Bowers, to the south-east of Danbury, at the level of below 200 feet.

Another significant fact in the composition of the Danbury gravels is the absence of Jurassic sandstones and of the large irregular unrolled flint nodules, which are common in the Glacial beds and in the post-Glacial gravels of the district. The Glacial and post-Glacial gravels also contain occasional pebbles of basalt, but I have never found any in the Danbury gravel.

The absence of Jurassic sandstones, large unrolled flints, and basalt indicates that the Danbury gravels were deposited before these rocks were brought into Mid-Essex during Glacial times.

The Danbury gravels are therefore free from the constituents introduced during the glaciation of the district.[1] The structure of the gravels also furnishes no evidence of their glacial origin. The beds are often false-bedded, and they are sometimes contorted and have pebbles standing on end; but I have not seen anything in the gravels which gives clear evidence of ice action.[2] The pebbles are never striated; their forms, though often faceted by wind action, are not those characteristic of the glaciated stones in boulder-clays or glacieluvial gravels; the irregular bedding is of the kind due to rapid currents of water, and the contortions may be explained by slipping down the clay slopes and by movements during the consolidation of the gravel. There appears to be no valid evidence for the glacial origin of the Danbury gravel. It may be objected that such evidence is afforded by the association of boulder-clay with these gravels. The Geological Survey map of the area (Sheet 1, N.E.) does not mark any boulder-clay on the Danbury plateau, but it shows three small patches at lower levels on the adjacent hill-slopes, where they would be associated with redeposited Danbury gravels. I have not, however, been able to find at these localities any boulder-clay or any trace of it. Search for pebbles from the boulder-clay has been in vain. The most probable locality of the three (north-west of Bassetts) has been tested to the depth of two feet by a soil-sampler along a line

[1] My observations fully confirm those of Dr. Salter (1905, p. 31) as to the absence of glacial debris from the Danbury gravels and its presence in the later gravels along the existing river valleys. Wood (1867, p. 2) had remarked the easy recognition of the post-Glacial gravels by the presence of material derived from the Glacial beds.

[2] The eolithically chipped flints which Cunnington called 'glacioliths' indicate the action of severe frost, but not of glacial conditions.

across the middle of the area marked as boulder-clay, but without finding any trace of that material. The stones on this area include no Jurassic sandstones, no large unrolled flint nodules, and no chalk; and the proportions of the stones present, viz. 45 per cent subangular flints, 25 per cent pebbles from the Eocene shingle beds, and 30 per cent of quartz and quartzites, is much the same as in the adjacent redeposited Danbury gravel. The boulder-clay was perhaps marked here owing to the occurrence of some patches of soil which are white owing to the abundance of quartz sand and flint fragments. The boulder-clay in this area is confined to lower levels than the Danbury gravels.

The evidence for the pre-Glacial age of the Danbury gravels does not rest alone on the absence of material derived from the glacial beds. The general physiographic evidence appears conclusive. Glacial beds, including boulder-clay and glacial gravels, are widespread over the Mid-Essex plain at the level of about 200 feet, and they rise gradually north-westward to 300 and 400 feet; but around Chelmsford the boulder-clay does not occur on the higher ground, and the Danbury hills must have stood like an island above the level of the plain on which the boulder-clay was deposited. The main topography of Essex was pre-Glacial. The banks of the river which deposited the Danbury gravels had been cut down into lowland, and a fragment of the bed had been left on the Danbury plateau in pre-Glacial times. The Danbury gravels accordingly date from a period when the relief of Essex was very different from that of the present day. Hence, as the existing topography of Essex was pre-Glacial, and the Danbury gravels were laid down long before its development, the Danbury gravels are very long pre-Glacial.

The determination of a more precise age for these gravels depends on their position and the possible dates of introduction of their constituents. The quartzites and black cherts have probably come directly or indirectly from the Bunter pebble-beds of the Midlands. Some of the gravel heaps in the Midlands, as near Worksop and Nottingham, strikingly resemble those at Danbury owing to the abundance of similar quartzites. I submitted in 1913 a typical collection of Danbury pebbles to Professor Lapworth, Professor Boulton, and Mr. Raw, who agreed that most, though not all of them, could be matched in the Bunter pebble-beds of the Midlands.

If these gravels are not Glacial, then, by whatever route they came from the Midlands, they must have been introduced into Essex at a date earlier than the denudation of the plain, 160 feet lower, which now surrounds the Danbury hills.

Various suggestions have been made as to the route by which the foreign constituents in these gravels reached Central Essex. According to Dr. A. E. Salter (1905, etc.), whose detailed study of the composition of the gravels has thrown most important light on their relations, the non-local constituents came from the west down the Thames Valley or from the north-west across Hertfordshire through the Stevenage Gap. According to others (e.g. H. B. Woodward, 1909, p. 55) these quartzites and old cherts came from the south from the Weald. Prestwich (1890, p. 146) suggested their derivation from

Belgium, and this view received some support from Mr. Clement Reid's adoption (1882, pp. 56–7) of the same source for the non-local pebbles in the Forest Bed gravels.

The solution of this problem may be attempted by the discovery of the original home of the pebbles or by the study of their distribution in Essex. The application of the former method to the quartzites does not promise final results, for these rocks are so very durable that they were widely scattered in Mesozoic and perhaps later conglomerates, so that the determination of the original home of these pebbles may give no indication as to the direction of their last journey.

The study of the quantitative distribution of the foreign pebbles in Essex offers a more reliable method; and it is available in all the constituents of the gravels which were derived from outside Essex. Accordingly, at intervals during many years past I have estimated the percentage of the various pebbles in the chief Essex gravels. The results are shown in the table on pp. 534–5.

This table seems to me to prove the following conclusions:—

1. That the quartzites entered Mid-Essex from the north-west. For the quartzites and pre-Mesozoic cherts are most numerous and the pebbles are largest in the north-west of Essex, and they diminish in number and size to the south-east. Thus they occur to the extent of from 20 to 25 per cent in Danbury, and over 40 per cent near Great Dunmow; but they number only 3 per cent and even less near Burnham and Southminster.

2. That the Lower Greensand chert came from Kent and Surrey: for it is most abundant and occurs in largest pebbles in Southern Essex; it occurs at low levels as far north as Braintree, and even into Suffolk; but in the high-level Danbury gravels it is extremely scarce, and it is absent from North-Western Essex. That this chert was not obtained from the Lower Greensand of Bedfordshire or Cambridgeshire, which is not known to contain it, is further shown by its absence from the gravels in those counties.

3. That a series of felsites [1] (a name that may be conveniently used to cover the various igneous rocks referred to in Dr. Salter's memoir as rhyolite) are widely distributed in North-Western Essex; they are absent from the Danbury gravels, but occur even to the south-east of Danbury in the low-level gravels. According to the evidence collected by Dr. Salter the introduction of these felsites was pre-Glacial.

4. That the Danbury gravels did not contain any material introduced to Essex by ice.

5. That the Danbury gravels contain abundant pebbles derived from the Lower Eocene or Bagshot pebble-beds. The Danbury gravels are therefore later than the Lower or Middle Eocene; and the absence of glacial constituents and their position show that they are pre-Glacial.

The best chance of the determination of a more precise age is given by the distribution of the Lower Greensand cherts. They can only

[1] These felsites are probably derived from Lower Greensand conglomerates in East Anglia or in the adjacent counties.

have been introduced into Essex after the Wealden anticline had been sufficiently raised and denuded for the chert beds to have been exposed on the surface. The Wealden anticline has been often referred to as if due to a single uplift in the Oligocene, Miocene, or Pliocene; thus Prestwich (1890, p. 169) assigned it to the late Pliocene. The uplift, however, was the result of a long gradual movement, which began in the Cretaceous, since the upper zones of the Chalk thin out as they are followed from the Thames Valley southward toward the Weald. The denudation consequent on the uplift had exposed the Upper Greensand by a very early date in the Eocene, since Upper Greensand debris occurs in the Woolwich and Reading Beds (C. Reid, 1896, pp. 493–4). It would therefore not be surprising if the Lower Greensand had also been exposed in the Eocene; but, at the period of Dr. Irving's discussions with Messrs. Monckton and Herries as to the classification of the Bagshot Beds, the presence or absence of Lower Greensand cherts was the accepted test whether certain pebble-beds were Bagshot or redeposited Bagshots. Mr. Bromehead has, however, recently stated (Proc. Geol. Soc., 1913–14, p. 86) that Lower Greensand chert occurs in the upper Bagshot pebble-beds (Bartonian); and if so the Lower Greensand was exposed by the beginning of the Upper Eocene, and the chert from it could have been carried into Essex then or at some later date. Lower Greensand chert appears to be quite absent from the Essex Bagshot Beds, which are clearly much older than the Danbury gravels. Unless the country has been disturbed by differential movements the cherts can only have been carried to Danbury, at the level of 360 feet, from the nearest Lower Greensand outcrops, which are in Kent, some thirty miles to the south, when the Lower Greensand was exposed there at the level of not less than 700 feet above the sea; so that the uplift and denudation of the Weald must have been far advanced before the deposition of the Danbury gravels. The main uplift of the Weald may have been as early as the Oligocene; but it was certainly not later than Miocene, for the Lower Pliocene was a stage of great subsidence, during which the sea spread over the Thames estuary and over the worn-down northern side of the Weald as far south as Lenham and Wye and almost to Folkestone. How far the submergence extended to the west is doubtful; some patches of sand on the Chalk Downs to the south of London have been referred to the Diestian, but on evidence which appears inadequate.

The Lower Greensand chert must have been carried from Kent to Danbury before the Lower Pliocene subsidence. The chert may have been washed into the low-level East Essex gravels at Southminster and Southend in Pliocene or later times, as the slope from the present outcrop of the Lower Greensand cherts near Maidstone would have been sufficient for its transport by river-action into South-Eastern Essex. But it would not have been possible for the river to have carried the Kent cherts on to the top of the now isolated Essex hills at Rayleigh, Langdon, or Danbury, which are as high as the outcrops of chert in Kent, except when the topography of South-Eastern Essex was quite different from the present.

TABLE OF PERCENTAGE

Altitude above Sea. Feet.		Sub-angular Flints.	Eocene Flint Pebbles.	Quartz and Quartzites.
200	Danbury Mission Hall	58	21	21
About 350	1 mile N. of Danbury to E. of road to Little Baddow	53 57†	26 17	21 25
180–190	Bassetts, Little Baddow (Bamfield)	51	27	22
160–170	,, ,, (,,)	67	16	17
150	,, ,, (Pear Tree Field)	45	25	30
About 240	Galleywood, S. of Chelmsford	8½	90½	—
About 240	,, S. of the Church	2	97	1
300	N.E. of Billericay	4	96	0
260	Porters Hall, near Stebbing (N.E. of Great Dunmow)	41	15	42½
370	Langdon Hills	5½	91	3½
About 110	1 mile N. of Witham	35	32	24
180–190	Wickham Bishop	55	15	25
205	Tiptree Heath	58	20	22
100	N.E. of road, 3 furlongs N. of Ulting	65	20	16
370	Epping Forest; Jack's Hill	20	15	20*
50	Southminster	43	51	·1
Under 50	Burnham-on-Crouch	59	32	3
Under 50	Between Southend and Shoebury Cliff	53	28	5
—	Walton-on-the-Naze	52–6	23·7	15·2
—	,, ,,	20	36	30
—	S.E. of Walton	32	24	26
162	Little Leighs	46*	21	32½
About 160	S. of Braintree (Rural District Com. Pit)	34½	24½	36½
25	Langford, 1½ m. N.W. of Maldon	52·4	21	25
45	Hoe Mill, 1m. N. of Woodham Walter Church	72	15	12
25	Little Hayes, Crouch Valley, near Rettenden	63	28	4½
—	Cromer Forest Bed Gravels	28·2	20·2	37·6
—	Herts, Gravels of Upper Plain	35		65
—	,, ,, Lower ,,	50*	30	20†
278	Horsington, 2 m. S. of Harrow	30	42	10
400–460	Barnet District	20	50	18*
—	Southern Drift from Rochester	60	20	0

[1] The term Brentwood Gravel is used for gravels associated with the Bagshot for those containing much quartzite and usually also abundant Lower Greensand

COMPOSITION OF ESSEX GRAVELS.

Lower Greensand Cherts.		Nature of Gravel.
0		
0	* Including 1 sandstone.	Danbury Gravel.
0	† 2 eoliths and 4 red flints.	
0		
0	No Greensand cherts or Jurassics; 1 large quartzite.	Redeposited Danbury Gravel.
0	(Area marked on Survey Map as Boulder-clay.)	
0	1 Sarsen-stone.	Bagshot Pebble-beds.
0	About ·05 % of liver-coloured quartzite in tiny pebbles $\frac{1}{4}''$ to $\frac{1}{2}''$.	,, ,,
0	Brentwood Gravels.	Brentwood Gravels.[1]
0	Felsite, $1\frac{1}{2}$ %.	Braintree Gravels.
0	1 specimen found at this exposure, but elsewhere small fragments of chert common.	,, ,,
9*	* Including ragstone (Prestwich, 1890, p. 132). Typical area of Braintree Gravels.	
—		,, ,,
—		
0	No Jurassics.	
10†	Prestwich. * Including 5 of lydianstone. † Including ragstone.	Westleton Beds of Prestwich. Braintree Gravels.
6		
6	H. B. Woodward and Bennett in Whitaker, 1889, p. 423.	
14		
8·3*	* Recorded as "Chert and sandstone (from Lower Greensand?)" (Whitaker, 1877, Mem. Geol. Surv. Sh. 48 S.E., p. 17).	East Essex Gravel.
14	Prestwich, 1890, p. 128.	
18	,, ,, p. 129.	
0	* 14 % of large unrolled glacially transported flints; fragments of *Inoceramus*.	Glacial Gravel.
1	Sandstones $3\frac{1}{2}$ %. Felsite present.	
·4	$1\frac{1}{5}$ % Jurassic sandstones, black jasperoid, basalt, silicified rhyolite, Mesozoic fossils. Palæolithic flakes (not in situ and possibly from soil above the gravels).	Post-Glacial Gravel.
1		
—	Sandstones from Boulder-clay.	
·8	Ironstone 12 %; hard sandstones 8 % (Reid, 1882, pp. 55-6).	
—	Hughes, 1868, p. 283 = 50 % quartz; 10 % quartzite; 5 % jasper, quartzite-conglomerate, etc.	
—	* Including a few bits of ironstone, Jurassic fossils, etc.; † 10 % quartz, 10 % quartzite.	
18†	Prestwich, 1890, p. 137.	† Includes ragstone.
12†	* Includes 3 % lydianstone, etc. (Prestwich, 1890, p. 136).	
20†	Prestwich.	

Pebble-beds and containing no non-Essex material; and the term Braintree Gravels Cherts, and situated at a lower level than the Danbury Gravels.

The transport of the Lower Greensand chert on to the Essex hills was therefore pre-Diestian, and the Danbury gravels cannot be later than the end of the Miocene.

It may be suggested that Miocene gravels would not have lasted so long in such a situation. But as patches of Bagshot and even older pebble-beds occur in similar positions in the Thames Valley there is nothing very surprising in the survival of a Miocene gravel at Danbury. The Danbury hills owe their existence partly to the slow rate of denudation in a mature low-level country, and partly to the mantle of redeposited gravel on the hill-sides having protected the underlying clay from wind and rain.

The Mid-Essex Fault.—The age of the Danbury gravels is, however, complicated by the possibility that their present elevation may be due to uplift, for if so they might have been laid down in Pliocene times by some southern river, contemporary with that which deposited the Southminster gravels.

If the Danbury gravels stood alone this complication would seriously affect the question, but fortunately the high-level gravels at Rayleigh (alt. 260 feet) also contain Lower Greensand chert; and there is nothing to suggest their differential uplift. As the gravels in the Rayleigh hills must have received their Lower Greensand chert before the Diestian subsidence, the Danbury gravels must have received their scantier supply before that event.

That the Danbury gravels have been upraised by an earth-movement was first suggested by S. V. Wood, jun., who held that a bed of London Clay near Riffhams, to the north of Danbury, which occurs between two beds of the Danbury gravels, owed its position to an overthrust fault. The section is now obscure and overgrown, and in its present condition does not give any evidence in support of Wood's conclusion. The outcrop of the bed is now so weathered that it might be a redeposited clay. But as Wood examined this section when it was clear, and he was not likely to have mistaken rainwash for London Clay in situ, his interpretation of this section is not to be lightly dismissed, especially in view of the fresh evidence for a mid-Kainozoic dislocation along the line indicated by him. Thus the chalk surface under this part of Essex is not a uniform plane, as represented in Geological Survey Horizontal Section, No. 84, 1871; it is disturbed by well-proved irregularities. These irregularities in Mid-Essex are due to a disturbance, which was either a fault or a sharp fold along the line indicated by Wood. Among the evidence for this dislocation is the steep dip in the London Clay at Perry Wood, beside the Kelvedon railway; this dip has been attributed by Holmes to a fault. The Colchester earthquake of 1884 was probably due to a slip on the same or a parallel fault (Meldola, 1885, p. 185). Evidence for differential movement across the Chelmer Valley and for the extension of the fault from Billericay southward to the Thames near Cliff has been recently advanced by Mr. Boswell (1915, pp. 200–2, 205).

The most striking evidence is afforded by the Wickham Bishop bore, which proved that the beds at the base of the London Clay were inverted and repeated. This bore began at 234 feet O.D. and

yielded the following section: Soil 1½ feet, drift 41½ feet, London Clay 252 feet, Woolwich and Reading Beds 34½ feet, London Clay repeated 53½ feet, Woolwich and Reading Beds 39 feet, Thanet Sand 56 feet, Chalk 693 feet; total, 1,180 feet.

Dalton (1882, p. 16) attributed this succession to a reversed fault. Mr. T. V. Holmes definitely (1891, pp. 199–200) and Mr. Whitaker doubtfully (1886, pp. 168–9) accepted this view. S. V. Wood (1881, p. 504; 1886, p. 79) referred the disturbance to an S-shaped fold. The difference between a fold or a fault is comparatively immaterial, and this bore strongly supports Wood's conclusion that a powerful post-Eocene dislocation must cross Mid-Essex. This movement, according to Wood & Dalton, was earlier than the high-level gravels at Wickham Bishop; but according to Dr. Salter the movement was later than the gravels, for it uplifted them. The probabilities are in favour of Dr. Salter's view. The age was certainly pre-Glacial and was probably Pliocene. This age is indicated by the following considerations:—

1. The direction of the dislocation is north-east to south-west, and not east to west.

2. The Colchester earthquake shows that the movements along this line have not yet ceased.

3. The Mid-Essex range, which extends from Tiptree through Wickham Bishop, Danbury, and Billericay, was caused by this uplift. The lower Chelmer was already in existence before this uplift, which, being later than the Chelmer, must be much later than the Danbury gravels, since they were deposited before the erosion of the Chelmer and other Mid-Essex river valleys.

REFERENCES.

Dalton, W. H. 1882. "The Blackwater Valley": Trans. Epping Forest and Essex Nat. Field Club, vol. ii, pp. 15–18, pl. i.

Fisher, O. 1868. "The Boulder-clay at Witham and the Thames Valley": Geol. Mag., Vol. V, pp. 98–100.

French, J. 1891. "On the Occurrence of Westleton Beds in North-West Essex": Essex Nat., vol. v, pp. 210–18.

Holmes, T. V. 1891. "The Geology and Scenery of the Club's Voyage from Maldon to Chelmsford, August 8, 1891": Essex Nat., vol. v, pp. 197–202.

—— 1904. "Visit to the Light Railway between Kelvedon and Tollesbury": Essex Nat., vol. xiii, pp. 249–50.

Hughes, T. McK. 1868. "On the Two Plains of Hertfordshire and their Gravels": Quart. Journ. Geol. Soc., vol. xxiv, pp. 283–7.

Meldola, R. and White, W. 1885. "Report on the East Anglian Earthquake of April 22, 1884": Essex Field Club, Special Memoirs, No. 1, x, 224 pp., pl. iv.

Prestwich, J. 1890. "On the Relation of the Westleton Beds . . . with some observations on the period of the final elevation . . . of the Weald and of the Thames Valley, etc.": Quart. Journ. Geol. Soc., vol. xlvi, pp. 84–181, pls. vii, viii.

Reid, Clement. 1882. *The Geology of the Country around Cromer* (Mem. Geol. Surv. England and Wales, Sh. 68 E.), x, 137 pp., 1 pl.

—— 1896. "The Eocene Beds of Dorset": Quart. Journ. Geol. Soc., vol. lii, pp. 490–6.

Salter, A. E. 1905. "On the Superficial Deposits of Central and Parts of Southern England": Proc. Geol. Assoc., vol. xix, pt. i, pp. 1–56.

WHITAKER, W. 1886. "Some Essex Well Sections": Trans. Epping Forest and Essex Nat. Field Club, vol. iv, pp. 149–70.

—— 1889. *The Geology of London and of part of the Thames Valley* (Mem. Geol. Surv., 2 vols.).

WOOD, S. V. 1867. (1) A Memoir in explanation of the structure of the Glacial and Post-Glacial beds, mapped in a Geological Survey of the Ordnance Sheets Nos. 1 and 2; comprising the Thames Valley between London and the sea, and the Valleys of the Lea, Roding, Ravensbourne, Cray, Darent, Crouch, and Chelmer Rivers, and of the Blackwater Estuary and other subordinate valleys; incorporated with which is an Essay upon the general structure of the Post-Glacial system over the East, South-East, South, and part of the South-West of England. Folio; 54 double pp. and 2 maps. January, 1867. MS. Memoir in Library of the Geological Society.

—— 1870. "Observations on the Sequence of the Glacial Beds" (part ii): GEOL. MAG., Vol. VII, pp. 61–8, 1870.

—— 1881. "Further Remarks on the Origin of the Valley System of the South-Eastern Half of England, prompted by the Result of a Boring near Witham in Essex": GEOL. MAG., N.S., Dec. II, Vol. VIII, pp. 502–5, 1881.

—— 1886. "On the Sand-pit at High Ongar, Essex, with a note on Mr. W. H. Dalton's Paper on the 'Blackwater Valley'": Trans. Epping Forest and Essex Nat. Field Club, vol. iv, pp. 76–86.

WOODWARD, H. B. 1903. "Geology" in the Victoria History of the County of Essex, vol. i, pp. 1–24, map.

—— 1909. *The Geology of the London District* (being the area included in Sheets 1–4 of the Special Map of London): Mem. Geol. Surv. England and Wales, 1909, viii, 142 pp., 1 map.

II.—SUGGESTIONS FOR A REVISED CLASSIFICATION OF TRILOBITES.

By H. H. SWINNERTON, D.Sc., F.G.S., F.Z.S., Professor of Geology, University College, Nottingham.

(*Concluded from the November Number, p. 496.*)

SUB-ORDER MESONACIDA.

NEVADIA is the earliest and the most primitive member of the Mesonacidæ, and as shown by Walcott[1] may be regarded as representing the ancestral type of this family. The same authority shows that the Paradoxidæ have descended from the Mesonacidæ. *Redlichia*[2] also exhibits features which link it with the Paradoxidæ and the Mesonacidæ.

Beecher[3] places *Zacanthoides* near *Paradoxides*. Woodward[4] suggests that this genus descended from *Holmia*. Walcott[5] couples it with *Albertella* as a member of the Paradoxidæ which exhibits approximations to the Mesonacidæ. Reed[6] agrees with this conception of its affinities. *Zacanthoides* and to a less extent *Albertella* may therefore be regarded as forms which, like *Paradoxides*, have descended from Mesonacidæ. They have, however, attained a more advanced stage in caudalization, a feature which taken with their probable origin from a different section of the Mesonacidæ would justify the formation of a separate family for these two genera, viz. Zacanthoidæ.

[1] Smiths. Misc. Coll., vol. liii, p. 249, 1910.
[2] Walcott, Proc. Wash. Acad. Sci., vol. vii, 1905; op. cit., 1910, p. 254.
[3] Op. cit., 1897, p. 191.
[4] GEOL. MAG., 1902, p. 539.
[5] Op. cit., 1910, p. 254.
[6] *Palæontologia Indica*, ser. xv, vol. vii, p. 9, 1910.

Beecher[1] placed *Remopleurides* alongside *Paradoxides*. If allowance be made for its Aeglinoid type of adaptation to nocturnal habits[2] the similarity of this genus and its allies to the Paradoxidæ and Mesonacidæ is evidenced by such features as the close proximity of the long crescentic eyes to the glabella, the comparatively wide free cheek, the small pleural lobes, and the telson-like pygidium.

These four families—Mesonacidæ, Paradoxidæ, Zacanthoidæ, and Remopleuridæ—thus constitute a compact and natural group forming a sub-order of the Opisthoparia, to which the name Mesonacida may be given. It should be noted that true facial sutures have come into existence within the limits of this sub-order.

In *Marella* the great spines borne by the carapace and possibly the marginal position of the eyes are adaptations to planktonic mode of life.[3] Allowing for this, if the genus 'foreshadows' any one type more than another that type is *Nevadia*, for it possesses a long series of segments apparently without pleural lobes and ending in a telson. On the other hand, *Nathorstia*, as shown by the character of its glabella, the width of the fixed cheek region, and the great size of the pleural lobes in the trunk and tail segments, is a persistent member of the stock which foreshadowed the type of Trilobite represented by *Conocoryphe*, *Ellipsocephalus*, and *Burlingia*. In it, however, caudalization is far advanced for so lowly a form. If with the exception of the tail-region this Trilobite preserves the primeval condition of Trilobites other than Mesonacidæ, the absence of facial sutures in it implies that true sutures have developed independently at least three times, viz. among Mesonacida, among other Opisthoparia, and among Proparia.

Sub-order Conocoryphida.

Conocoryphe and a few other genera which differ slightly from it belong to the family Conocoryphidæ. Beecher,[4] speaking of the Opisthoparia, says, "from a phylogenetic standpoint the family Conocoryphidæ is at the base of this extensive order." Its narrow marginal free cheeks, the diminution anteriorly and clearly marked segmentation of its glabella, the presence of eyelines, the great number of free segments, the micropygous condition, all indicate its primitive character.

Some of the genera included by Beecher in the Conocoryphidæ are now referred to that unwieldy, heterogeneous, and ill-defined family the Olenidæ. Two Lower Cambrian genera belonging to this family call for special attention, viz. *Ptychoparia*[5] and *Protolenus*.[6]

Apart from the presence of eyes the general details of structure of *Ptychoparia* (Fig. 3*d*) are either the same as or progressive developments from those of *Conocoryphe* (Fig. 3*c*). The most marked difference is in the shape and size of the free cheeks. This is due to the shifting of the ocular portion of the facial suture from the margin

[1] Beecher, op. cit., 1897, p. 191.
[2] Cf. Dollo, *La Paléontologie Ethologique*, Bruxelles, 1910, p. 415.
[3] Ibid., p. 409.
[4] Op. cit., 1897, p. 189.
[5] Type species, *Ptychoparia* (*Conocephalites*) *striata*, Emmrich.
[6] G. F. Matthew, Trans. Roy. Soc. Canada, vol. xi, p. 144, 1893.

towards the glabella. The points of intersection of the suture with the margin are the same as in *Conocoryphe*. The posterior one in both genera is quite close to the genal angle, thus causing the free cheek to taper gradually into the genal spine. As to the rest of the body, caudalization has advanced slightly.

Protolenus (Fig. 3*f*), like *Ptychoparia*, evidently arose from a conocoryphid-like stock before the eyes had been lost and before the pygidium had increased to any extent. But these two genera have pursued different lines of development. In *Protolenus* (Fig. 3*f*) the head-shield is wide and short, tending to a tetragonal outline rather than to a semicircular as in *Ptychoparia*. The ocular portion of the facial suture has shifted towards the glabella, but the post-ocular portion has participated in the same movement, so that the point of intersection with the posterior margin is some distance from the genal angle. The free-cheek thus comes to bear a close resemblance to that of the Mesonacida, but the great size of the fixed cheek and the importance of the pleural lobes at once shut it out from that sub-order.

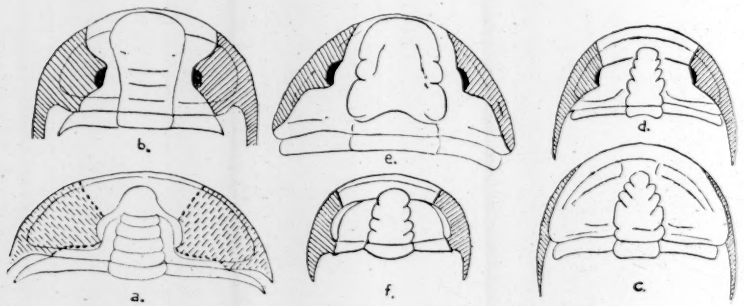


FIG. 3.—Types of Opisthoparian head-shields. *a*. *Nevadia* (modified after Walcott), dotted and broken lines are hypothetical; *b*. *Paradoxides*; *c*. *Conocoryphe*; *d*. *Ptychoparia striata* (after Barrande); *e*. *Protolenus* (after Matthew); *f*. *Calymmene* (after Salter).

These two genera lie near the starting-points of two divergent offshoots of a conocoryphid-like stock.

Protolenus, as its name happily suggests, lies at the base of one offshoot, to which the family name of Olenidæ (s. str.) should be strictly limited. This includes all those genera grouped by Lake [1] into the Continuæ, Abruptæ, and Inermes.

Ptychoparia, on the other hand, is the basal type of a separate group, which may receive the family name of PTYCHOPARIDÆ, and which includes *Ptychoparia*, *Protypus*, *Euloma*, *Sao*, *Triarthrus*, *Liostracus*, *Bavarilla*, *Neseuretus*.

In both families the minor modifications, such as the rotation of the pre-ocular suture towards the middle line, the widening of the glabella anteriorly, the smoothing out of the glabellar furrows, pursue parallel courses of development.

[1] Monogr. Palæont. Soc., 1907, p. 51.

Other families group themselves round the Olenidæ (s. str.) and the Ptychoparidæ respectively. In some cases the connexion is close and is evidenced by known transitional forms. In other cases the relationship is distant, and only the inability to find a more suitable place justifies putting them here.

The Proetidæ are a small compact family within which all stages in the increase of free and reduction of fixed cheeks and in caudalization may be seen. Beecher[1] derives them from *Arethusina*, which Reed[2] classes with the Proetidæ and Raymond[3] as one of the Olenidæ. Those features in which this genus differs from the Olenidæ (s. str.) it has in common with *Cyphaspis*. It seems probable, therefore, that the Proetidæ have arisen from an Olenid stock.

In the family Orycтocephalidæ, Raymond[4] includes *Oryctocephalus*, *Zacanthoides*, *Olenoides*, and *Neolenus*. As already seen *Zacanthoides* belongs to the Mesonacida. Reed[5] places *Dorypyge* with *Oryctocephalus* and *Olenoides*. A comparison of these three genera shows that they all possess the *protolenus* type of cheek region. Reed[2] further considers them related to *Parabolina* and *Parabolinella*. But the latter are essentially Upper Cambrian forms in which caudalization has hardly begun. The former are Lower and Middle Cambrian types in which caudalization has already advanced to the isopygous stage. Had the order of appearance in time been reversed close relationship could not have been denied; as it stands, the Oryctocephalidæ must be regarded as a separate branch of the same stock, a branch in which caudalization began early and rapidly reached its acme. Were it not for the spines they might be described as occupying the same position in the economy of the Lower and Middle Cambrian as did the Asaphidæ in the Ordovician.

The Ptychoparidæ, though not so large a family as the Olenidæ, seem to stand near the point of origin of many more families.

The close affinity of the Solenopleuridæ is too evident to call for discussion.

The Dicellocephalidæ include *Crepicephalus* and *Dicellocephalus*. Of the first-named genus Walcott[6] remarks, "the essential elements of the head are generically identical with those of *Ptychoparia striata*, but the pleuræ and thoracic segments and pygidium vary in a marked degree." Certainly the free cheeks are only a slight advance on the ptychoparian owing to the shifting of the ocular suture closer to the glabella and to the posterior margin. *Dicellocephalus* differs from *Crepicephalus* chiefly in being isopygous. The whole family bears the marks suggestive of the adaptation of the ptychoparian type to fossorial habits.

As shown by Pompeckj[7] the Calymmenidæ and the Homalonotidæ are derived from the Ptychoparidæ through *Bavarilla* and *Neseuretus*.

[1] *Amer. Journ. Sci.*, vol. iii, p. 195, 1897.
[2] Op. cit., 1904, p. 74.
[3] Zittel's *Textbook*, 1913, p. 715.
[4] Op. cit., 1913, p. 716.
[5] *Palæontologia Indica*, 1910, p. 10.
[6] *Cambrian Fossils of Yellowstone Park*, Monogr. 32, U.S.G.S., 1899, p. 460.
[7] Op. cit., 1898.

Their predominant peculiarity, viz. the intersection of the facial suture with the margin at the genal angle, is evidently an inherent tendency in the Ptychoparian constitution, for it manifests itself in *Triarthrus*.

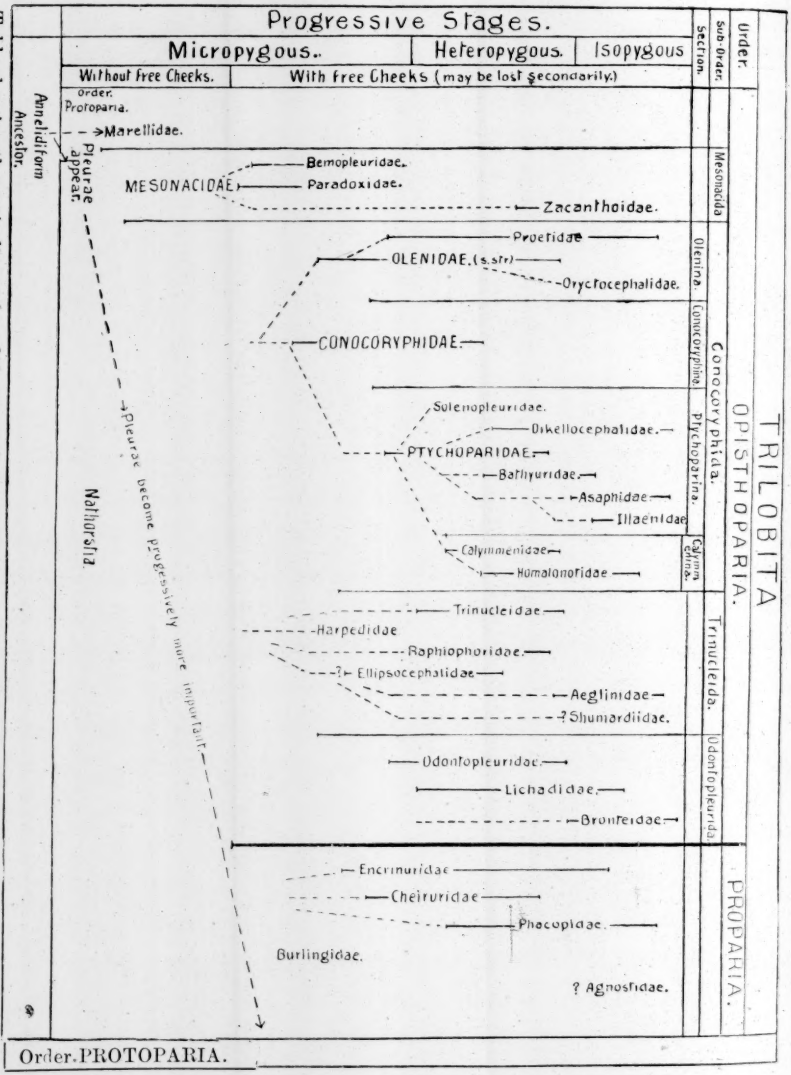


Table showing the main lines of modification which occur amongst Trilobites and the probable general relation of Trilobite families to one another.

Raymond[1] rightly emphasizes the very primitive condition of the Middle Cambrian Asaphid *Ogygiopsis*, and traces from it the main

[1] Trans. Roy. Soc. Canada, ser. III, vol. v, p. 116, 1911.

lines of Asaphid development, one of which culminates in the Illænidæ. Woodward[1] draws attention to the close resemblance of *Bathyuriscus* from the Middle Cambrian to the young of *Ogygiopsis*, a resemblance which proves the Bathyuridæ to be an early offshoot of the ancestral Asaphid stock. Though the requisite connecting links are missing, this stock must probably be looked for among the Ptychoparidæ, for *Bathyuriscus* differs from the latter only in the degree of progressive development such as the broadening of the glabella and axis, the shifting of the ocular portion of the facial suture closer to the glabella, the more advanced caudalization, and concomitant reduction in number of the free segments. The three families, Illænidæ, Asaphidæ, and Bathyuridæ, constitute the isopygous section of the Ptychoparian type. In the more specialized members the post-ocular facial suture shifts away from the genal angle, thus pursuing a course divergent from that seen in the Calymmenidæ and the Homalonotidæ. In every case this is associated with a shifting of the eye, not only towards the glabella, but also towards the posterior margin. This specialization proceeds quickly within the Bathyuridæ and less quickly in the main branches of the Asaphidæ.

All these families whose descent may be traced back to the Conocoryphid type of primitive Trilobite may be placed in the sub-order Conocoryphida, which may be broken into four sections, viz. *Conocoryphina*, *Olenina*, *Ptychoparina*, and *Calymmenina*.

Sub-order Trinucleida.

The three families, Trinucleidæ, Raphiophoridæ, and Harpedidæ, are usually grouped together. The first two closely resemble one another in the short trunk and tail region, with only five or six free segments and the pygidium, which is wider than long. The last is linked on to the first through the Trinucleid genus *Dionide*, which, as shown by Reed,[2] has many points in the head-shield which indicate its intimate relations with *Harpes*, *Harpides*, and *Erinnys*. The remainder of the body, however, retains the primitive micropygous condition with numerous free segments, which decrease in size posteriorly. Here again, however, *Dionide* bridges the gap, for, whilst some species, e.g. *Dionide Richardsoni*,[3] have an almost typically Trinucleid trunk and tail, others, e.g. *Dionide Lapworthi*,[3] are like *Harpes* in outline, and though the pygidium is large show clear indications of numerous segments.

Whilst *Harpes* shows the type of trunk and tail possessed by the ancestral Trinucleid, the characters of the ancestral head-shield[4] must be reconstructed from other genera; thus, *Ampyx* retains its narrow marginal cheeks, *Orometopus* its eyelines and compound eyes, and both show that it did not possess a broad margin or limb, various species of *Tretaspis* and *Ampyx* retain indications of its segmented

[1] Geol. Mag., 1902, p. 532.
[2] Geol. Mag., 1912, p. 202.
[3] *Vide* F. R. C. Reed, Monogr. Palæont. Soc., 1903, pl. iv.
[4] It is conceivable that the absence of facial suture in *Harpes* is a case of retention of protoparian conditions.

glabella. This combination of characters carries the Trinucleid line of descent back to an early Conocoryphid-like stock which had not yet lost the eyes, and in which caudalization had hardly begun. The gap between *Conocoryphe* and known genera is, however, so great that it is necessary to establish a separate sub-order, viz. the Trinucleida.

The Ellipsocephalidæ fail to fulfil the conditions required of the Trinucleid ancestral stock, because their first few segments have already assumed an equality of size, and their remaining free segments, together with the small pygidium, are already shortened to such an extent as to produce an almost Trinucleid shape of body. This similarity to the Trinucleida may be due to parallel adaptation. On the other hand, it is not unreasonable to regard the Ellipsocephalidæ as an early offshoot of the same stock, and therefore subject to the same morphological tendencies as those which characterize the Trinucleida.

Gurich places the Aeglinidæ with the Trinucleidæ. They certainly exhibit the same type of trunk and tail region as that family and the Ellipsocephalidæ. They may be regarded as having the same relationship to the Trinucleida that the Remopleuridæ have to the Mesonacida or, in a less marked degree, *Nileus* to the Asaphidæ, viz. an adaptation to nocturnal pelagic or nektic mode of life.[1]

The Shumardiidæ seem also to possess claims to at least a provisional home among the Trinucleida inasmuch as nearly all their characteristics in head-shield and body shape are paralleled among the members of this sub-order.

These three families—Ellipsocephalidæ, Aeglinidæ, and Shumardiidæ—may be placed provisionally as an appendix to the Trinucleida.

Sub-order Odontopleurida.

Beecher,[2] speaking of the Odontopleuridæ (Acidaspidæ) and the Lichadidæ, says "these two families are closely related". The tendency to develop numerous spines is an adaptation characteristic of planktonic forms. The thinness of the carapace in the latter family is also characteristic of pelagic animals. These features may therefore be left out of account. The usual stability of the glabella in other families and sub-orders emphasizes the genetic and classificatory value of the strong tendency towards the breaking up of the glabella into separate lobes shown in these two families. Apart from this the free cheek in the less modified forms is large and of the Olenid type. There is at present an absence of connecting links between these families and any of the other sub-orders. Until such links are forthcoming a provisional sub-order, the Odontopleurida, may be instituted.

The Bronteidæ (Goldiidæ) present peculiar difficulty, for they are a clearly defined family with no known connecting links with other families. Beecher[3] points out the tendency in some species towards "a breaking up of the glabella into symmetrically disposed separate

[1] Cf. Dollo, *vide supra*.
[2] Op. cit., 1897, p. 197.
[3] Op. cit., p. 196.

lobes as in *Conolichas* and *Acidaspis*". He also draws attention to the reduction of the pygidial axis and extension of the limb as another feature in common with the Lichadidæ. He seems to suggest that the condition in the latter family is a declension from that in the Bronteidæ. But the number of free segments in the trunk is greater and the number of fused segments in the pygidium is smaller in the Lichadidæ than in the Bronteidæ. The difference here, then, is largely a difference in degree of caudalization. The Bronteidæ are not descended from the Lichadidæ, but they carry the Lichadid type of organization along lines parallel to and quite as advanced as some of those which characterized the Asaphidæ, cf. the isopygous condition, the shifting of the eye close to the glabella and to the posterior margin of the head-shield, the union of the facial sutures with one another in front of the glabella. These facts suggest that the Bronteidæ may be provisionally relegated to the sub-order Odontopleurida.

The Proparia.

The order Proparia is not a large one. It includes the families Burlingiidæ, Encrinuridæ, Cheiruridæ, and Phacopidæ. The three last call for no consideration here.

The family Burlingiidæ[1] is of peculiar interest because it carries the Proparia type back from the Tremadocian to the Middle Cambrian. It furnishes a type in which caudalization (Fig. 1*e*), if it has begun, has not advanced beyond the stage seen in the contemporary *Paradoxides*. The great development of the pleural lobes and of the fixed cheeks which extend to the lateral margin of the cephalon removes this family further than the Mesonacida from the primitive annelidan or arthropodan type of trunk. Though so primitive in its trunk and tail regions and in the position of the pre-ocular suture, the relation of the post-ocular suture to the margin shows no sign of approximation to the opisthoparian condition. On the contrary, and in spite of the specialized position of the eye, it is the same as that found in the early stages of development of other Proparia and the highly specialized as well as the primitive Proparian genera. The points of intersection of the facial sutures with the margin in *Burlingia* must therefore be regarded as the primeval positions, and can only have been developed directly from the protoparous condition without the intervention of an opisthoparian stage.

III.—Notes on the North-Western Region of Charnwood Forest.[2]

By Professor T. G. Bonney, Sc.D., LL.D., F.R.S.

CHARNWOOD Forest, since 1891, the date of the last paper by Canon E. Hill and myself,[3] has been investigated by the Geological Survey. Though part of their map and the accompanying memoir have not yet been published, the general results of their work

[1] C. D. Walcott, Smiths. Misc. Coll., vol. liii, 1908.

[2] Read before the British Association at Manchester, Section C (Geology), September, 1915.

[3] Quart. Journ. Geol. Soc., vol. xlvii, p. 78, 1891.

have been announced by Professor W. W. Watts, by whom most of it was executed. As we stated at the time, we were far from being satisfied with some important points in our own conclusions; so that since my return to Cambridge I have studied my specimens and slices from the north-western region, which had presented to us the more serious difficulties. In 1891 I had been led to regard the characteristic rocks of Peldar Tor and High Sharpley as lava-flows, but considered the dominant rocks of Bardon Hill to be mainly pyroclastic.[1] Professor Watts, however, maintained the intrusive character of the first and second, while taking the same view as myself about the third. The lava-flow hypothesis had appeared to me the more probable, because I doubted whether a mass so large as the Peldar-Bardon porphyroid, if intrusive, could have maintained throughout a texture so uniformly fine-grained, and I had found in the Bardon quarries fragments of it embedded in rock which I then supposed to be a somewhat altered tuff, closely related to the High Sharpley lava. The breccias and the compact rocks of Bardon Hill, the one of which seemed to pass into the other, continued to perplex me, though after repeatedly studying them I became more inclined to regard them as an abnormal result of some kind of flow-brecciation. Having heard how greatly the Bardon Hill quarries had been enlarged, and that others had been opened on Peldar Tor, Canon Hill and I visited them last April and obtained both information and specimens which were very helpful in clearing up difficulties. In July I returned to this district in company with my friend Mr. R. H. Rastall, F.G.S., in order to verify one or two matters and examine a few outlying sections.[2] The specimens collected on these occasions, with those already in my possession, have been carefully studied, and it may be that I have benefited by the widened experience of almost a quarter of a century. The result has been, as I proceed to explain, to convince me that I formerly made the mistake of regarding too large a number of the rocks in the north-western district as pyroclastic in origin.

The Peldar porphyroid is so uniform in its characters, megascopic and microscopic, that it is practically impossible to distinguish specimens got at the Tor from those of Bardon Hill. They have a dull green, slightly rough ground-mass, which, under the microscope, mainly consists of roundish or rather oblong felspars, often about one-thousandth of an inch in length, separated by a filmy yellowish or greenish mineral, in many cases more suggestive of

[1] In our Charnwood papers I accepted all responsibility for the microscopic work.

[2] I gladly tender my thanks to the owners or managers of the quarries—to Mr. B. N. Everard, of Bardon Hall, for giving us the help (as he was himself unable to meet us) of his foreman manager, Mr. R. B. Grant, who personally conducted us over Messrs. Ellis & Everard's quarries and called our attention to particular sections which other geologists had found interesting. The knowledge thus acquired has led him to put aside specimens which strike him as remarkable, and I am indebted to him for two of much importance, which are mentioned in this paper. I have also to thank Mr. J. H. Robinson, of the Peldar Tor quarry, and Mr. J. T. Briers, of the Forest Rock quarry, for much kindly assistance.

a mica than a chlorite. In this ground-mass are scattered crystalline grains of quartz and of a reddish felspar, ranging up to about one quarter of an inch across. But for microscopic details I may refer to what has been already published,[1] as well as for those of the Sharpley porphyroid, which has a rather compact purplish ground-mass. This, under the microscope, is fairly clear with ordinary light, though containing many granules of a dark iron oxide, and with crossed nicols shows a speckled structure, suggestive of devitrification, interspersed by a few tiny felspar laths, probably a plagioclase. In fact, under the microscope, a 'spotty' structure characterizes the one rock, a 'speckly' structure the other. But, as formerly mentioned, the Peldar rock seems occasionally to put on a Sharpley aspect, and the spots in the one, though fairly plain with ordinary light, almost disappear with crossed nicols, as if it might pass into the other.

In 1891 we saw, as already stated, on the more northern side of the middle[2] quarry at Bardon Hill, fragments of the Peldar porphyroid in a rather schistose and brecciated compact purple porphyroid, then supposed to be a volcanic ash, the material of which had a general resemblance to that at Sharpley, and was practically identical with one which occurred in the breccias of Ratchet Hill and of other places in the Forest. Our facts were correct, but not our interpretation of them, as can be most quickly explained by a brief account of our recent observations. In April we saw but little of the compacter purplish porphyroid, the place of which seemed to have been taken by the ordinary greenish rock of the Bardon quarries, but specimens collected prior to 1891 confirm our notes that the former varied from an almost compact rock, indistinguishable from some fragments observed on Ratchet Hill and elsewhere, to a porphyroid only differing from that of Sharpley by its smaller crystals of felspar and quartz. In this rock, to which we then assigned a pyroclastic origin, we found "fragments and possibly lenticular streaks" of the Peldar porphyroid to be fairly common,[3] and in April last we observed similar occurrences in the ordinary Bardon rock, and a sharp junction between masses of the two could be traced at one place both on the floor and in the wall of the pit. We came also to the conclusion that the compact and the brecciated varieties of the Bardon rock passed one into another without any break, and that in the latter the boundaries of the fragments were sometimes not very definite, for in one variety they almost resemble reddish clouds on a dull green ground. Their colour also exhibits the same uncertainty, but the breccias with yellowish-green fragments seem now less abundant than those with

[1] Quart. Journ. Geol. Soc., vol. xxxvi, pp. 342–5, 1880.

[2] Now the fourth, counting upwards from the lowest. The quarry in 1878 was divided into two stages. In 1880 one was opened a little farther down the hill, so the middle quarry of 1891 (Q.J.G.S., vol. xlvii, p. 86) is the lower of our earlier papers. There are now six quarries one above the other, the fourth, counting upwards, corresponding with our 'middle', and two quarries (besides trial holes) on the north-western side, one of them less than 100 feet below the summit (912 feet).

[3] Quart. Journ. Geol. Soc., vol. xlvii, p. 82, 1891.

reddish. The difference also between fragments and matrix is often less marked under the microscope than it appears to the unaided eye, and in some slices it is almost impossible to determine the precise line where the one ends and the other begins. The structure of both occasionally approaches microgranular, but is more often intermediate between the Peldar and the Sharpley types, inclining on the whole to the latter. In fact, the relationship between these porphyroids and the brecciated Bardon rocks has of late impressed me more strongly than ever before. Certain specimens may present characters which seem to be distinctive, but on studying others we find these gradually disappear,[1] the Peldar 'spotting' being interstreaked with a Sharpley 'speckling' as if the two varieties were imperfectly mingled. At the Tor quarry a rather compact purplish porphyroid, like that at Bardon, appears to be intrusive in the Peldar porphyroid, and the former shows by the arrangement of its microliths a slight fluxional structure; but, as in the other locality, the difference between the two porphyroids is more conspicuous to the unaided eye than under the microscope. The compact porphyroid, however, sometimes has a greenish tint, and at Bardon these colour varieties may be seen irregularly interbanded, the one passing into the other. Even the Peldar porphyroid at the Tor quarry sometimes shows a purplish 'bloom'; in fact, I am now convinced that the colour differences in the north-western district largely depend on the subsequent action of water, which has converted some of the more minute constituents into viridite.[2]

The large quarry on Peldar Tor is rudely crescent-shaped, and has been worked back from the road towards the rugged summit of the hill, being carried to a greater depth on its western side. The intrusive compact porphyroid sometimes makes sharp junctions with the Peldar porphyroid, but sometimes partly melts it down, so that the relics of the latter produce a sort of streaking or local mottling in the former. Running obliquely up the wall of the quarry, on its north-western side, is a 'greenstone' dyke, the thickness of which cannot easily be estimated owing to the direction of the section, but perhaps a couple of yards would not be far wrong. It has evidently suffered much from crushing, the effects of which are not nearly so perceptible in the porphyroid. A slice cut at right angles to the shear planes shows under the microscope (1) streaky patches of

[1] Signs of fluxion, as well as of subsequent pressure, may sometimes be noticed, and the former seem to be more common in the neighbourhood of a junction. Many of the Pre-Cambrian and Ordovician felstones, in which some amount of fluxion is perceptible, show, in a single slice, appreciable variations in their microscopic structures.

[2] Viridite is an old term which I think might well be retained. Of course it is vague, but so is the thing thus denoted. It often is obviously made up of tiny flakes, but not seldom has hardly any effect on polarized light (perhaps because they are so minute). Some of the larger flakes appear to be a chlorite, while others have more resemblance to a greenish mica; others may, perhaps, be serpentine. In fact, I believe it to be often more or less of a mixture, varying in composition with the mineral which has been replaced; the above-named colour change from purple to green meaning the formation of a hydrous iron silicate.

viridite, often in very minute flakes, but sometimes large enough to be recognized as a chlorite; (2) rather irregularly outlined scales up to about ·01 inch in length and ·002 inch in thickness, pale green to almost colourless, giving with crossed nicols fairly bright tints and straight extinction, probably a hydrous mica; (3) many grains or granules, with rather irregular outlines, under ·01 inch in diameter, water-clear, and possibly a secondary felspar. In this ground-mass iron oxides, mostly ilmenite, now largely leucoxene, are fairly abundant, in shape rather elongated and irregular. Probably the rock was once a basalt or dolerite. 'Greenstone' dykes are not very rare in the Forest rocks, sometimes in fairly good preservation, but at others so crushed that I once mistook them for slates.[1] Like those at Stewart's Hay, this basic dyke shows the effects of pressure more conspicuously than the rock in which it is intrusive.

The Forest Rock quarry has been opened by the road from Leicester to Whitwick in the southern flank of the Spring Hill moorland, some 300 yards west of the Peldar Tor quarry. It is already a large one with a deeper excavation on the western side of the entry. The dominant rock is a porphyroid, with quartzes[2] and felspars about the size of those at Peldar Tor and Sharpley, in a ground-mass which in colour and texture more resembles the latter; in fact, the specimens remind us now of the one, now of the other. Sometimes, however, the felspars exhibit a roughly parallel arrangement, and the rock then looks more schistose than is usual on Sharpley. This, however, is to a large extent due to a subsequent pressure, which in the part of the pit where it was most conspicuous must have acted roughly at right angles to the direction of fluxion. Both varieties of this porphyroid are associated with a rather compact purplish one, which to the unaided eye resembles those cutting the Peldar rock in the quarries at the Tor and on Bardon Hill. It is distinctly the intruder, sometimes showing a sharp junction and even including fragments, occasionally over a foot across, of the other one, which here and there it has almost digested.[3] Both rocks, but especially the more porphyritic one, contain fragments of the greenish fine-grained speckled rock, so commonly enclosed in the Peldar porphyroid at the other two localities.

In this pit, however, the compact intrusive rock, which to the unaided eye so closely resembles those at Bardon Hill and Peldar Tor, differs from these under the microscope. It has undergone a greater amount of secondary change than one would have anticipated. The felspars, which are the best preserved constituents, form a plexus of laths, in length ranging about ·01 inch, and indicating by their extinction angles a plagioclase near to oligoclase. The intervening ground-mass consists of an iron oxide, brown or

[1] Quart. Journ. Geol. Soc., vol. xxxiii, pp. 785–6, 1877. The mistake is noticed, id., vol. xlvii, p. 91, 1891.

[2] Locally of a reddish colour.

[3] We find sometimes, within 2 or 3 inches of a junction, solitary grains of quartz and half-destroyed felspars, which can only have been derived from the Peldar porphyroid.

brownish red in colour with reflected light, of another which similarly viewed is an earthy grey, sometimes almost white (when it may be leucoxene), and of a minute clear mineral, possibly representing a pyroxene. In this ground-mass larger grains are scattered, also replaced by alteration products, probably once an iron oxide, perhaps ilmenite, and a minute mineral, giving bright tints with crossed nicols, sometimes apparently replacing a felspar.[1] One or two imperfect phenocrystals of that mineral appear in the slice, with a grain of quartz; they are probably, it is almost certainly, derivative. The secondary changes make it difficult to give a name to this rock, but I think it probably a rather basic porphyrite, and that in chemical composition it does not differ so much from the other two as its structure might suggest.

The microscopic structure of the ordinary Bardon Hill rock was described in our papers of 1880 and 1891, so that I need only add that, as stated above, I am now more impressed than formerly by the close resemblance of its matrix, and even of most of the included fragments, to that of the Peldar and Sharpley porphyroids. The fragments, indeed, sometimes exhibit a fairly marked fluxion structure, but the ground-mass of even these seems, with crossed nicols, identical with that which surrounds them. Yet to the naked eye they stand out quite plainly. For instance, in some trial holes above the highest working on Bardon Hill, a variety was obtained which is locally called the 'sultana rock', because reddish spots about as large as those raisins are scattered in the usual dull green ground. But under the microscope we find it very difficult to make out where the one begins and the other ends.

The rock outcropping on the summit of Bardon Hill so much resembles an agglomerate that I formerly felt no doubt of its pyroclastic origin, but my work in the pits lower down made another examination necessary, in which I was aided by Mr. Rastall. The presence of fragments is indubitable, for they project on weathered surfaces from about a quarter to half an inch, subangular to rather rounded in shape, and in diameter from less than an inch to about four inches. They were not, however, quite so large or so numerous as my memory had suggested, being perhaps most abundant in an outcrop, about forty yards from the tower on its eastern side. These fragments, so far as I could see, represented both the 'purple porphyritic' rock and another fairly common in the breccia quarried below.[2] The outcropping masses assume in weathering a rather rounded outline, and one part, a few yards S.S.E. of the tower, faintly suggests a stratification, dipping roughly N.N.E. at an angle rather less than 45°. My friend admitted that a pyroclastic origin seemed to be the more natural interpretation, but after visiting one or two of the pits below he felt obliged to favour the fluxion-breccia hypothesis. A slice from the matrix of a specimen, collected on this occasion, proves that, if we allow for the effects of weathering, it is indistinguishable from the specimens obtained lower down the hill.

[1] In that case it may be a zeolite, but Mr. Rastall suggests to me that some grains more resemble dolomite.

[2] A pale red with dull green spots.

If this rock is an agglomerate, so are they; if they are igneous rocks, so is it; and I am now compelled to abandon the former and adopt the latter conclusion.

This, however, makes it impossible for me to accept the view expressed by my friend Professor Watts in his excellent account of Charnwood Forest.[1] Arguing against our view that the Peldar and Sharpley porphyroids might be lavas, he says that an excavation at Bardon Hill had disclosed porphyroid exactly like that of Peldar Tor, "intrusive into the Bardon rocks. The junction was irregular, the margin of the porphyroid was chilled and fine-grained, and the edge of the Bardon ashes was hardened and turned red."[2] But in 1887, if not earlier, I had examined junctions of the two rocks and had seen, as already stated, lumps of the Peldar porphyroid, a few inches in diameter, completely enclosed in the ordinary Bardon rock.[3] Of these relations I have full notes, written on the spot, and possess a specimen showing a junction of the two rocks. Last July I saw a similar lump of Peldar porphyroid, fully seven inches in diameter, embedded in the ordinary Bardon rock, in which one could detect half-digested remnants of the other.[4] Another large specimen showed, as I had already seen in the quarry, a sharp junction between the two rocks, with no change in the ordinary structure of the porphyroid; which, however, taken as a whole, is not always quite uniform in its texture. Thus, though it may be an intrusive of some kind, a sill or a rather thin laccolite,[5] I am convinced that it is anterior to the Bardon Hill rock.

The second section, quoted by Professor Watts to prove the intrusive character of the Peldar porphyroid, I have not seen, because it was exposed in the excavation for the Blackbrook dam, which was undertaken some time after we had given up work on the Forest. That showed the porphyroid to be intrusive in "rocks of the Blackbrook stage". But as these underlie the Maplewell series, the porphyroid, even if it were a lava at Bardon, might very well be intrusive into them, for its texture, if it be not that of an ancient lava, must, I think, indicate consolidation at no great depth from the surface.

We had not sufficient time at our disposal to examine the whole of that part of Ratchet Hill[6] which we formerly considered to be

[1] *Geology in the Field*, p. 770; also ch. ii in Mem. Geol. Surv., Expl. Sheet 141 (C. Fox-Strangways), p. 5.

[2] Loc. cit., p. 776.

[3] Supposing this to be pyroclastic, I interpreted the other as a fragment ejected in advance of a lava-flow (represented by the Peldar porphyroid); but in any case such a relation makes it in the highest degree improbable for the latter to be the intruder.

[4] For the preservation of this, which (with the second mentioned) is now in the Sedgwick Museum, I have to thank Mr. Grant. The only difference between it and the specimen collected by myself is that the 'Bardon' rock in the one case is greenish, in the other purplish in colour, which, as said above, may be disregarded. Under the microscope they are identical.

[5] I have never detected any hardening of the Bardon rock at the junction with the Peldar porphyroid, and doubt whether the redness mentioned can be interpreted as a contact phenomenon.

[6] A notice of it is given: Q.J.G.S., vol. xxxiii, p. 777, 1877.

pyroclastic and on much the same horizon as the Peldar Tor porphyroid, for a well-grown plantation now occupies the ground. Sharpley porphyroid crops out in the south-east part and is replaced, in going westward, by a breccia,[1] the fragments in which represent the 'purple porphyritic' and the 'syenitoid' mentioned in our notes on the fragmental igneous rocks,[2] and their matrix, indeed the rock as a whole, very closely resembles that on the summit of Bardon Hill. Under the microscope the two are substantially identical. According to my memory (confirmed by my notes) the rock further west becomes more obviously pyroclastic, but until I can re-examine that portion I will say no more than that a rock similar to the ordinary one of Bardon Hill makes its appearance to the west as well as to the south of the porphyroids.

With Mr. Rastall, I once more visited the Swannymote rock. It offers great difficulties, as our former description shows,[3] and some of them have not been removed by the further study of specimens. The occasional mottled aspect of the rock recalls the Bardon Hill breccia, and its microscopic structure bears a close resemblance to that of the Sharpley porphyroid, except that the phenocrystals of quartz and felspar are rather smaller. But how are we to explain the presence of the slate fragments? To the unaided eye they do not appear more altered than those common in other parts of the Forest, and under the microscope they show no sign of contact metamorphism. It has been suggested to me by Dr. Bennett and Dr. Stracey that a variety of the Sharpley porphyroid might have broken through a bed of "slate agglomerate", which can be traced "from the north-east right round the Forest" and "seems to mark a satisfactory horizon";[4] and has swept these fragments along with it. This suggestion deserves very careful consideration, for though the presence of these fragments and their condition seem at first sight strongly in favour of a pyroclastic origin, we may explain the absence of appreciable contact metamorphism by supposing the temperature of the intrusive magma to have been comparatively low.[5] The basalts and dolerites of the Fifeshire coast produce but slight changes in the rocks which they have pierced and sometimes include as fragments. Limestones and dark shales are hardened and the latter changed in colour, becoming a greenish-grey; sandstones are altered to a kind of quartzite, and if red (as in Arran) are bleached, but that is all. They are never even partially melted like the vitrified sandstones of Saxony. The Gross Weilberg basalt in the Siebengebirge contains in its outer part numerous fragments, apparently unchanged, of a trachytic tuff through which it has broken. This explanation seems to me the more probable because I cannot find any other evidence of a pyroclastic origin in the Swannymote rock and am unable to separate its microscopic structure from that of the other porphyroids in this north-western district.

[1] Well exposed in a little ridge running roughly north and south.
[2] Q.J.G.S., vol. xlvii, p. 95, 1891.
[3] Q.J.G.S., vol. xlvii, p. 85, 1891.
[4] *Geology in the Field*, p. 774. Possibly also, they think, the underlying "felsitic agglomerate" may have been similarly treated.
[5] We noticed also that the slate fragments exhibited a rough parallelism.

To conclude: my recent studies in this part of Charnwood Forest have impressed me more strongly than before with the close resemblance of the ground-mass in the porphyroids, the Bardon rock, ordinary and brecciated, and the brecciated rock in the middle part of Ratchet Hill. The fragments also, which occur in the indubitably pyroclastic rocks of the Maplewell series, differ but little from these. They have led me to think that I erred in considering this Bardon rock pyroclastic, to which I may add that of part of Ratchet Hill and perhaps a little more in the north-western district. While the microscope in some cases reveals structures which might well be interpreted as indicative of a pyroclastic origin, these often prove on further examination to be more probably consequences of some kind of flow-brecciation. Besides this, increased experience of the microscopic structure in the ground-mass of the above-named rocks, and in those, such as lavas, where the origin cannot be doubted, have shown me that they can hardly be due to the alteration of volcanic dusts, as I once supposed possible, but that they agree, as said above, with those characteristic of a rather glassy lava, either in the strict sense of that term or as a shallow intrusive. How far their present structure is original and how far due to subsequent devitrification I cannot at present feel quite certain. The devitrification is not so conspicuous as in the old rhyolites of the Wrekin, Pontesford, the Bangor-Llanberis district, St. David's and Boulay Bay (Jersey), and I incline to regarding the microlithic felspar laths mentioned above as original. So the Sharpley rock and its allies may very well have had a vitreous base, but this point must be left for further study.[1] Other volcanic districts, such as Auvergne, the Siebengebirge, and the Phlegræan Fields, prove that lavas varying considerably in texture and chemical composition can be ejected from orifices in one and the same district, and the Lipari Islands show us obsidians, in close proximity to sub-crystalline rhyolites and andesites, and in one case even to rocks which are almost basalts. Indeed, my specimens from these islands, in which subsequent devitrification is improbable, show wider differences than I have observed in Charnwood.

[1] I write this after spending a long time over rock slices from other districts in my collection, and comparing those from Charnwood with others, like them very ancient, in which the structure was less 'blurred' by the formation of secondary minerals, or in which any subsequent change was improbable. There must, no doubt, be some micromineralogical secondary change in the ground-mass, but the main question is, how far that 'spotty' structure of the Peldar rock, which disappears with crossed nicols, is a consequence of this. This disappearance favours an affirmative answer, but I find a generally similar structure exhibited by slices in a (purchased) collection of Hungary rocks, where it must, I think, be primary, and it occurs in a slightly more pronounced state at the Lower Quarry, Enderby (near junctions with a sedimentary rock considered by Mr. A. J. Lowe to be Stockingford Shales), and in the two quarries between Narborough and Croft. But in a slice labelled Thonstein porphyr, Mohorn, near Freiberg, I find a 'spotted' structure which mostly disappears with crossed nicols, and in rock from the Wrekin district, which must have been devitrified, I find indication of a very clear separation of the more felspathic from the more quartzose part, which may be secondary. For a discussion of devitrification, see Quart. Journ. Geol. Soc., vol. lix, p. 440, 1903. So at present I prefer to regard the question as still unsettled.

Another conclusion follows from the above-named close similarity of the ground-masses: that the final consolidation, if the porphyroids are intrusive, not extrusive, rocks, must have taken place within a comparatively short distance from the surface. Hence I believe that the group on the whole is volcanic, and agree with the conclusions as to the history of the district, which were so clearly and succinctly expressed in 1911 by my late friend and old pupil, Mr. A. J. Jukes-Browne.[1]

As this paper has shown, I regretfully admit having made serious mistakes about the origin of some of the Charnwood rocks. First in time is that of supposing the Peldar and Sharpley porphyroids to have been exceptional forms of altered tuffs, and then, after this had been proved erroneous, in supposing the dominant Bardon rock to be pyroclastic. In extenuation I may plead that in 1871, when Canon Hill and I began our work in Charnwood, the microscopic study of rocks was comparatively in its infancy, and that I was misled, prior to the publication of our first paper in 1877, by an eminent foreign petrologist, who had assured me that the porphyroids of the Ardennes were not really igneous rocks (a statement for which I could find no grounds on examining them in 1882[2]). Also, that even ten years later the effect of subsequent pressure on rocks of igneous origin was not so well understood as it is at the present time; and lastly, that even now I have no hesitation in saying that these Charnwood rocks, owing to their exceptional obscurity of structure, due in part to the formation of secondary minerals, are more difficult than any with which I have had to deal in a fairly wide experience. But I have long been convinced that when one has made and published a mistake, it is the wiser course to let this be known, lest it should continue to mislead younger geologists.[3]

IV.—The Carrara, Massa, and Versilia Marble District.

By C. S. Du Riche Preller, M.A., Ph.D., M.I.E.E., F.G.S., F.R.S.E.

I. Introductory.

THE range of the Apuan Alps, commonly called the Carrara Mountains, is an offshoot of the Apennines, trending N.N.W. to S.S.E., parallel to the Mediterranean littoral, from which it rises within a distance of barely four miles to a maximum height of 6,000 feet above sea-level. Exclusive of the outer belt of the more recent strata, the Triassic formation, within which the saccharoidal

[1] *Building of the British Isles*, p. 35.

[2] See Proceedings of the Geologists' Association, vol. ix, p. 247.

[3] It is only right to add that, after arriving at the conclusions stated in this paper, I found them to be substantially identical with those already reached by Dr. F. W. Bennett and Dr. B. Stracey, of Leicester. To the one I am indebted for helpful letters and copies of notes communicated to the Geologists' Association, and to the other for kindly lending me some two dozen rock slices from this north-western district, which, having been recently made in Germany, were especially useful as being rather thinner than my own, of English handiwork and for the most part at least a quarter of a century old. It is fortunate that, as now the quarries are being so rapidly enlarged, they and the Forest generally are being watched by such well-qualified observers as these and other Leicester geologists.

marble beds are situated, covers about 25 by 13 kilometres or about 130 square miles, of which the marble zone proper represents 64 square miles or about half. The range is bounded on the north by the Aullela valley in the Lunigiana district;[1] on the east by the Serchio valley in the Garfagnana district; and on the south by the Serchio valley in the Province of Lucca. The marble district, whose western part faces the Mediterranean, comprises the three divisions of Carrara, Massa, and the Versilia in the corresponding parallel valleys of the Carrione, Frigido, and Serravezza Rivers. The Versilia division, which forms part of the Province of Lucca, is composed of the Seravezza, Stazzema, and Arni subdivisions, of which the last-named lies on the eastern watershed of the Apuan range. The Versilia division also includes Pietrasanta, Camajore, Massarosa, and the well-known watering-place of Viareggio, near the last-named of which are situated extensive subaqueous deposits of a peculiarly coarse-grained, sharp macigno sand. These deposits, formed as a delta in a lacustrine expanse by the River Serchio, constitute an important and indispensable adjunct of the marble industry as grinding material for the numerous marble saw-mills in the three parallel valleys already referred to.

Up to 1880 parts of the marble district had been investigated chiefly by Savi, Coquand, Cocchi, and De Stefani, whose views were in part concordant, in part conflicting; but it was only subsequently, in the early 'eighties, that the systematic and comprehensive geological survey of the entire range of the Apuan Alps was carried out by Lotti and Zaccagna, of the Royal Italian Mining and Geological Department, under the direction of Professor Meneghini, of Pisa. This survey was completed in the 'nineties by the publication of the Geological Contour Map of 1 : 25,000 (2·54 inches per mile), together with numerous sections. It was in the period of that survey that the present writer had his professional headquarters in the district for several years, during which he acquired an intimate knowledge of every part of it[2] and had frequent opportunities of discussing and verifying the conclusions of those distinguished geologists.[3] It will, therefore, not be out of place to briefly review the outstanding features of that unique and justly famed district from personal experience and observation.

II. Physiographical Features.

If the range of the Apuan Alps could be reconstructed as it was after its being raised in Miocene times, it would represent a flat

[1] Lunigiana was the ancient Roman Luna district, the Carrara marble being then called Marmor Lunensis. The Apuan Alps were inhabited by a warlike tribe, the Apuani, subdued by the Romans 180 B.C.

[2] In a prize paper, Proc. Inst. Civ. Eng., vol. ciii, 1891, "The Carrara Marble District Railway," the author gave a summary description of the district.

[3] The Memoirs and Notes on the district by Lotti and Zaccagna in the Bollettino del R. Comitato Geologico d'Italia are the following:—

B. Lotti: vol. 1881, pp. 1, 85, 419; and *Carta Geol. d'Italia*, 1910, p. 372.

D. Zaccagna: vol. 1880; vol. 1881, pp. 1, 476; vol. 1896, p. 214.

B. Lotti is now Chief Engineer of the Royal Mining and Geological Department, Rome. Cav. D. Zaccagna is Resident Engineer of the same Department and Director of the Mining Institute of Carrara; he is himself a Carrarese who has, in the words of Dante, "tra bianchi marmi la sua dimora."

ellipsoidal dome whose cupola reached an elevation of over 6,000 feet above sea-level. The initial pressure having been exerted on this part, as indeed on the whole of the Ligurian littoral from the south-west, viz. from the Mediterranean, it is on the side of that littoral that the Apuan Alps are marked by steep and precipitous declivities up to 45 degrees, while on its eastern side they fall away more gradually to the Serchio valley at an average inclination of 20 degrees. Accordingly, denudation and the formation of deeply cut narrow valleys by fluviatile and atmospheric agency proceeded much more rapidly on the western side, which therefore exhibits a series of sharply defined peaks denuded, in their upper parts, of vegetation and imparting to the range its imposing, conspicuously rugged, and Alpine character. On the eastern side, on the other hand, where the process of denudation was less rapid, the mountains, with one or two exceptions, have preserved their dome- or loaf-shaped summit outlines with steep sides, and also more of their original elevation, for it is here that the whole range reaches its maximum altitudes in Monte Pisanino and the neighbouring Monte Tambura. The direction of pressure is also evidenced by the fact that the strata on the western side are much more highly crystalline and resistant than the more fine-grained and softer eastern strata, which, consequently, have been all along the line greatly folded, bent over towards the east, and at many points totally reversed.

The range is thus composed of two series of mountains, viz. of the *pizzi* or peaks of the western, and of the *panie* or loaf-shaped eastern series, the former being about 24 kilometres, the latter about 12 kilometres in length, and the two running, not exactly parallel, but converging towards each other. The natural alignment of the range may therefore be described roughly as that of a two-pronged fork as shown in the plan (Fig. V), the intervening space between the two prongs being occupied by the Arni Valley, about 7 kilometres in greatest width at its upper end. The ends of the two prongs are marked by Monte Sagro (Carrara) on the west and by Monte Pisanino on the east; the junction of the two prongs coincides with Monte Altissimo in the Seravezza division, and the southern end of the fork extends towards Pania della Croce and Monte Forato in the Stazzema division. The altitudes of the principal Western Pizzi and the Eastern Panie, which are marked in the plan, are as follows :—

Western Series, 24 km.		m.	*Eastern Series, 12 km.*		m.	
Carrara	Monte Sagro	1749	Monte	Pisanino	1946	Carrara and Massa.[1]
	Pizzo d'Ucello	1782	,,	Cavallo	1889	
Massa	Cresta Garnerone	1800	,,	Tambura	1890	
	Monte Grondilice	1805	,,	Sella	1723	
Seravezza	,, Altissimo	1549	,,	Fiocea	1711	Arni.
Stazzema	,, Corchia	1677	,,	Sumbra	1765	
	Pania della Croce	1859	,,	Freddone	1487	
	Monte Forato	1230	,,	Ronchi	1350	

[1] This very conspicuous mountain, one of the highest of the series, is really a *pizzo*, its summit being a ridge not more than 10 yards long and barely 2 feet wide. Monte Forato is, as its name implies, remarkable for the great natural arched opening just below its summit.

The intervening Val d'Arni lies at an altitude of about 1,000 metres at its upper and of 900 metres at its lower end between Altissimo and Sumbra, where the Arni and Freddone torrents join and under the name of Turrite Secca are deflected to the east as tributary of the River Serchio.

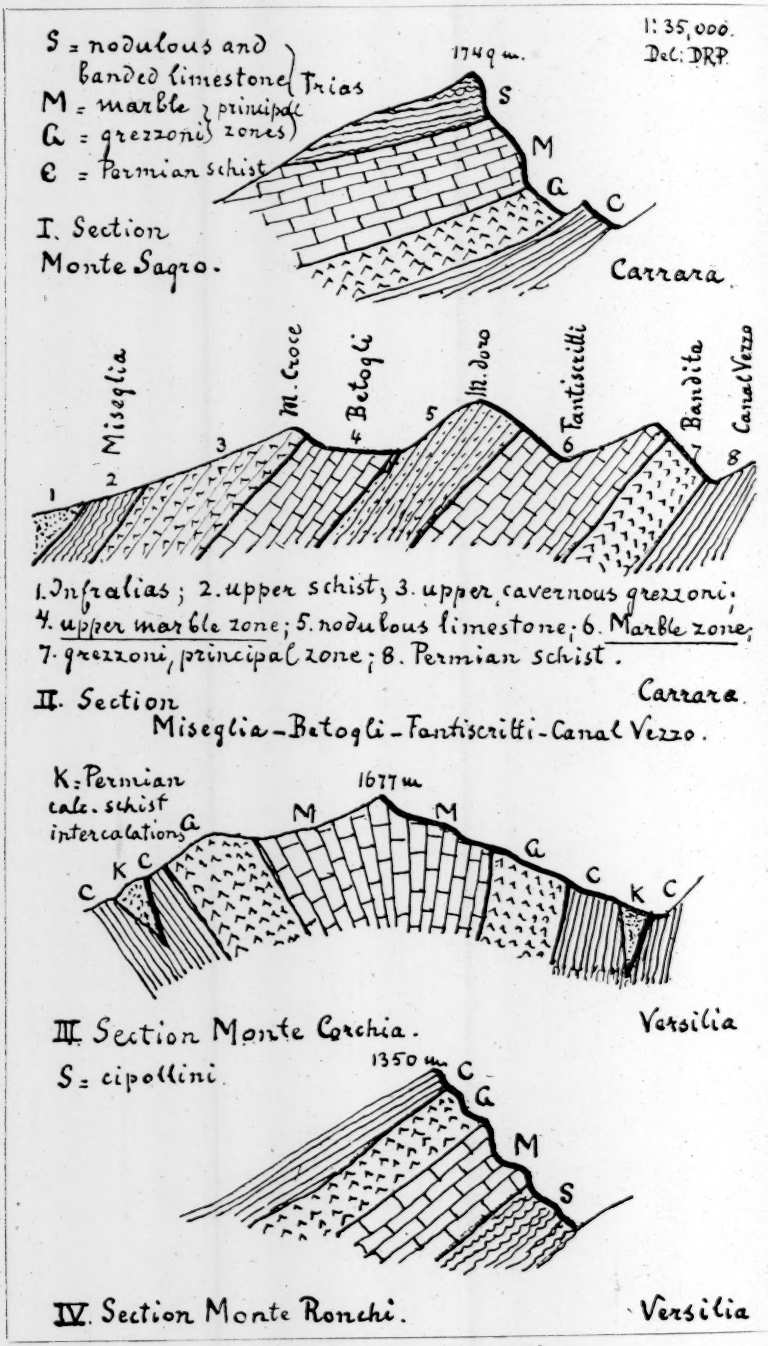
III. The Geological Structure.

The flat, fork-like curves formed by the crest lines of the two series also constitute the direction of the two great anticlinal folds of the range, the intervening Val d'Arni being the corresponding syncline. The two principal folds are not, however, simply uniform anticlines, but are composed of a succession of anticlinal and synclinal flexures which, beginning at the Vinca Pass north of Monte Sagro at the western and at Monte Pisanino at the eastern end, converge and merge into each other near Monte Altissimo and thence extend to the Stazzema end of the range. The extraordinary multiplicity of these flexures renders their co-ordination extremely difficult, the more so as in many of them, notably in the eastern series, the stratigraphical sequence is reversed, while, more especially at their junction near Monte Altissimo, and also near Renara in the Massa division, the strata exhibit extraordinary contortions which only long and patient study and sections of minute detail can unravel. The sections given in Figs. I to IV represent some typical examples, Fig. I showing the normal anticline of Monte Sagro, Fig. II a lower part of the same anticline, with the complete stratigraphical sequence from Miseglia to the Betogli and the Fantiscritti quarries above, viz. north-east of Carrara; Fig. III the normal syncline of Monte Corchia in the Stazzema, and Fig. IV the totally reversed stratigraphical sequence of the contorted flexure of Monte Ronchi in the Arni division, in the junction zone of the two great folds.

All the principal mountains exhibit flexures, more or less accentuated, not only along the precipitous ridges of the crest lines and on the denuded mountain-sides, but in the marble quarries, as well as in the cuttings and tunnels of the Carrara Marble Railway, all of which thus offer a multiplicity of revealing sections. In some isolated cases, where the visible part of a flexure is too acutely bent, there is a rupture of the lowest syncline or of the uppermost anticlinal stratum; but however twisted or reversed the flexures may be, there is throughout the range a total absence of faulting in the sense of fracture or dislocation of the strata. The very fact of the constant succession of normal and abnormal flexures admits of co-ordinating them as components of the two great folds which constitute one of the characteristic features of the range.

IV. The Stratigraphical Sequence.

Proceeding from the Mediterranean littoral upwards into the valleys of the three main divisions, the lower hills, which form the outer fringe of the range about 4 kilometres from the sea, are found to be composed of much folded Eocene alberesi limestone and macigno sandstone, succeeded by Cretaceous and then infra-Lias dolomitic limestone strata. The town of Carrara is built on old alluvial conglomerate resting on those strata. The infra-Lias thence extends



FIGS. I–IV.—Sections of Apuan Alps.

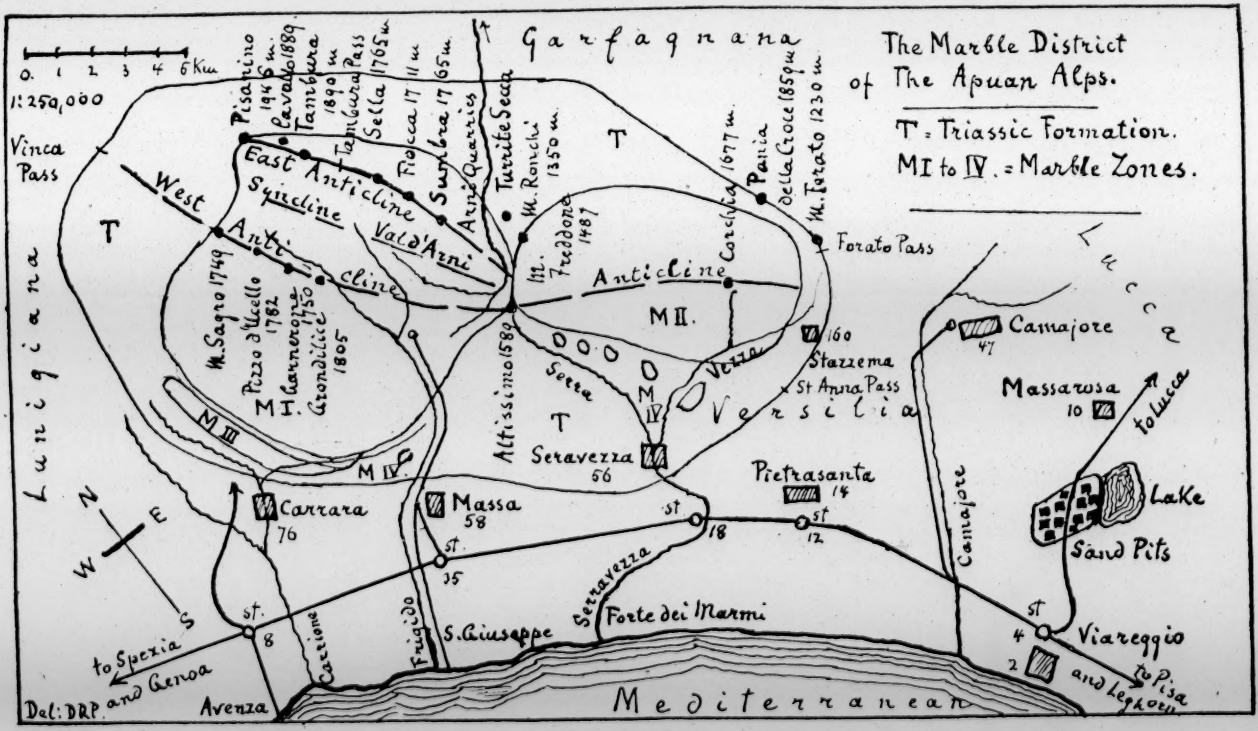


FIG. V.—The Marble District of the Apuan Alps.

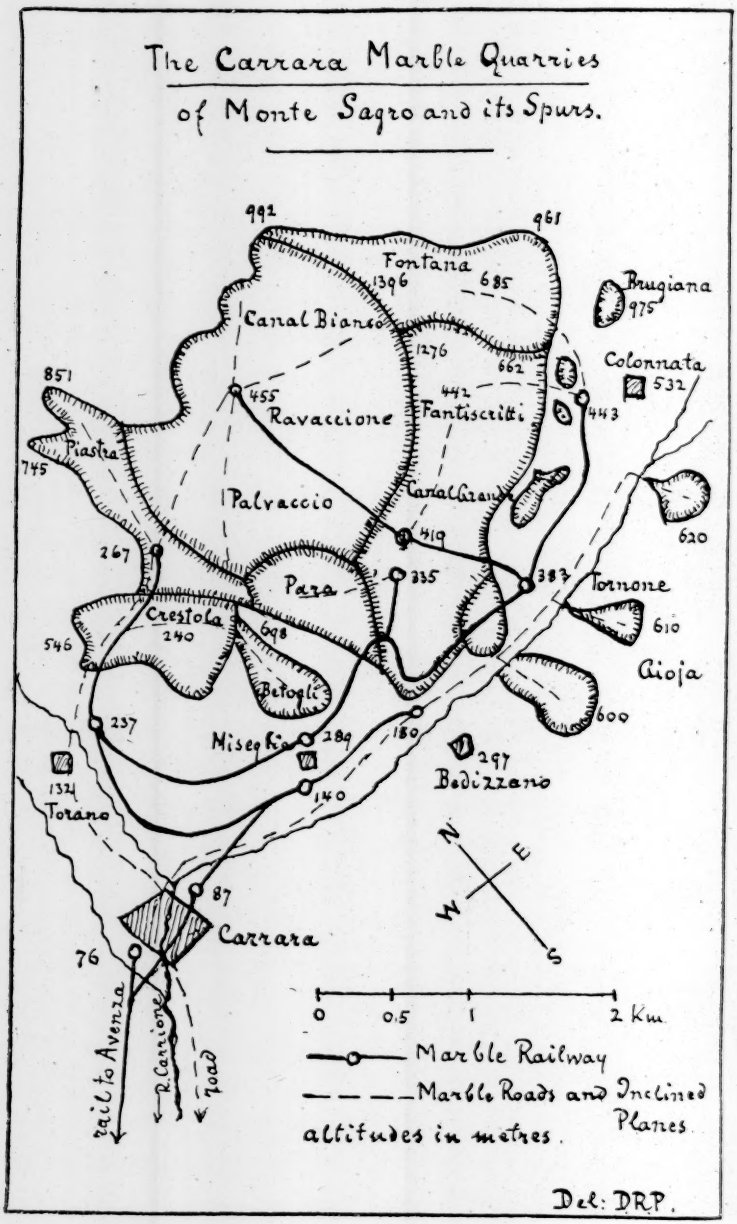


FIG. VI.—The Carrara Marble Quarries, Monte Sagro.

as far as Miseglia, about 1 kilometre north of Carrara, at which point begins the sequence of the Triassic and older rocks. From here, at altitude 240 metres—and about the same level in the other divisions—the succession, omitting the minor alternations—may be summarized as follows:—

		Depth in metres.
MESOZOIC.		
I. Upper Trias.	1. *Upper Schist, Marble, and Limestone Zone.*	
	(*a*) Upper Schist, sericitic and chloritic, with pseudomacigno sandstone . .	300
	(*b*) Cipollini and Upper, cavernous Grezzoni, semi-crystalline and dolomitic . .	
	(*c*) Upper Marble, white, statuary, bardiglio, veined, and breccia	300
	(*d*) Banded and Nodulous Limestone, grey and yellowish	200
	2. *Principal Marble Zone*, white, statuary, bardiglio, veined, and breccia . . .	1,000
II. Middle Trias.[1]	*Principal Grezzoni Zone*, dolomitic, semi-crystalline, dark-grey, brown, and whitish limestone	500
PALÆOZOIC.		
III. Lower Permian.	*Central Schist Zone*, dark grey, micaceous and gneissose, with calcareous, talcose schist intercalations	1,000
		3,300

It is thus seen that the upper and the principal saccharoidal marble zones together represent a visible depth of no less than 1,300 metres, over three-quarters of a mile. As shown in Figs. I to IV, the normal sequence of strata is uniformly the same throughout the three main divisions of the district, the marble of the principal zone resting normally always on the principal grezzoni beds, and underlying the banded and nodulous limestone of the upper series, except in abnormal or reverse flexures. The strata of the upper series frequently alternate with each other, as shown in Fig. II; hence the marble of that series is always associated with one or more strata of that zone.

V. The Central and the Upper Schists.

The central schists constitute the lowest formation and the nucleus of the range, and round and above them appear concentrically all the successive Triassic series. These central schists were formerly regarded variously as of Archæan, Silurian, or Carboniferous age; but the discovery in 1880 by Lotti and Zaccagna of abundant *Orthoceras* and *Antinocrinus* fossils in the frequent calcareous schist intercalations, notably near Fonte Mosceta in the depression between Monte Corchia and Pania della Croce in the Versilia (Stazzema) division (vide *K* in Fig. III), enabled Professor Meneghini of Pisa to assign the central schist formation definitely to the Palæozoic.[2]

[1] The Lower Trias is, in the Apuan Alps, so sparsely represented by a coarse sedimentary conglomerate underlying the Middle Trias grezzoni at a few isolated points of the range, e.g. near Vinca, Pizzo d'Ucello, and in the Arni region, as to be negligible. The conglomerate marks a transition from Upper Permian to Trias.

[2] "Nuovi Fossili delle Alpi Apuane": Proc. Verb. Soc. Tosc. Scienze Naturali, November 14, 1880.

Subsequently, in 1883 and 1885, Zaccagna, who at that time surveyed both the Grajan and the Western Maritime Alps on the Italian side,[1] showed conclusively that not in the former (nor in the St. Gothard schists), but in the latter is found the analogy with, and the equivalent of, the Apuan central schists, the uniform parallelism of the schists and the overlying grezzoni being in both cases precisely the same. Moreover, the fossils found in the Maritime Alps, notably in the Tanaro valley, were confirmed by Professor Portis[2] of Pisa as indubitably Upper Palæozoic, and hence it is due to Zaccagna that the long debated age of the Apuan central schists was finally determined as Lower Permian.[3]

Between the Permian and the Upper Triassic schists there is a very essential difference. Apart from their totally different stratigraphical position, the Permian schists are distinguished by their dark and predominantly gneissose, the Upper Triassic schists by their lighter, essentially micaceous and lustrous, sericitic texture. On the eastern side of the range, the upper schists often pass into so-called pseudomacigno sandstone; it is only on the western side that they are more crystalline, sericitic, and chloritic, and, owing to minute quartz nodules, sometimes simulate a gneiss-like appearance. In the extremely rare cases where the lower and upper schists appear in juxtaposition, e.g. for a short instance near Canevara in the Frigido valley (Massa), owing, not to any faulting, but to the lenticular thinning out of the normally intermediate strata, they graduate into each other. The Permian schists, moreover, nowhere—except in a similar case of lenticular thinning out in the Arni region—are seen in direct contact with the principal marble zone, whereas the Upper Triassic schists are frequently associated with the marble of the upper and also of the principal zone. This intimate association of all the members of the Triassic series, their constant alternation, thinning out—sometimes completely—and compensating each other, and the consequent absence of faulting, constitute indeed the great characteristic feature of the lenticular structure of that Apuan formation.

The maximum outcrop of the Permian schists occurs in the middle part of the Frigido valley (Massa), whence they extend south-east to the Stazzema division, north-west to Monte Sagro and beyond, and east to Monte Tambura and the Arni region. The Upper Triassic

[1] "Alpi Graje": Boll. R. Com. Geol., 1892, p. 322. "Alpi Occidentali (Marittime)": ibid., 1887, p. 416.

[2] "Piante fossili Valle Tanaro, Alpi Marittime": ibid., 1887, p. 417. The fossils of the Middle Trias grezzoni were determined by De Stefani, P.V.S.T. Sc. Nat., vol. 1880; those of the Upper Trias series by Meneghini, "Fossili Triassici Alpi Apuane": ibid., vol. v, p. 693; and by Canavari, ibid., vol. v, p. 184. Thus, the palæontological evidence of the Apuan Alps is practically complete. The best palæontological and petrological collection of the range, apart from the local one of Carrara, is that of the University of Pisa.

[3] The present writer proposes to deal more fully in a future paper with this Lower Permian formation as distinguished from the Upper Permian verrucano formation. The Permian range of the Maritime Alps forms the divide between Southern Piémont and the Italian Riviera, known as the Montgioje Mountains, where the Tanaro, an affluent of the Po, has its source.

schists, on the other hand, together with cipollini and nodulous limestone, constitute an outer belt, forming, among others, the summits of Sagro, Pisanino, Tambura, Fiocca, and Sumbra, while the rugged crests of Pizzo d'Uccello, Garnerone, and Altissimo are—in the last-named case in a reverse flexure—composed of grezzoni. In the anticlinal folds of Monte Maggiore—a marble spur of Monte Sagro—and of Monte Sella, as well as in the syncline of Monte Corchia, the principal marble zone reaches to the very summits. Pania della Croce, on the other hand, is, in its upper strata, composed of Liassic bluish-grey limestone.

VI. The Marble Beds.

The lenticular marmiferous masses of the Apuan Alps are composed of the four principal groups shown in the sketch-plan (Plate I). The first and largest of these embraces the bulk of the Carrara and Massa, as also the Altissimo, Arni, Sumbra, and Tambura beds. The second group adjoins the first near Monte Altissimo, in the Seravezza division, and thence extends to Monte Corchia and to the end of the Stazzema division. These two groups belong entirely to the principal marble zone directly overlying the Middle Trias grezzoni. The third and fourth groups, on the other hand, belong to the upper marble zone, the third group forming the lenticular mass of Crestola and Betogli in the Carrara division adjoining the principal zone, while the fourth group comprises the smaller, isolated lenticular beds of Monte Rotondo, Trambiserra, Capella, and Costa in the Serra and Vezza valleys of the Seravezza division, as also the outlying Brugiona and Campaccio beds in the Carrara and Massa divisions. The Crestola and Betogli beds of Carrara are separated from the principal marble zone by nodulous and banded limestone; the isolated lenticular masses of the fourth group are all intercalated between the schists, cipollini, and cavernous grezzoni of the upper series.

The varieties and gradations of marble which compose the four groups are substantially the same in all the three divisions. The great bulk of marble is in all cases the ordinary white and highly crystalline, from bianco chiaro (clear white) to the more common yellowish and bluish, representing about 75 per cent of the total, while the statuary proper represents about 10 per cent, and the rest of 15 per cent is made up of the dark and pale blue bardiglio, the blue and violet-veined, and the variegated breccia varieties.[1]

[1] The total annual output of the practically inexhaustible quarries (over 600) of the whole district now reaches 400,000 tons of marble in blocks and for slabs, tiles, ornamental and sculptural purposes, of which Carrara represents about 66, Massa 14, and the Versilia 20 per cent. The 150 saw-mills in the three valleys consume about 130,000 tons of Viareggio sand per annum, almost as much as the total output of sawn marble. The wastage of marble in quarrying and in the other operations amounts to about 10 per cent of the total.

The term "Sicilian Marble" mentioned in a recent paper (Geol. Mag., 1915, p. 290) is not used in the district, much less is it a geological term. It is an obvious and purely commercial misnomer, dating from the time of Napoleon I's embargo on exports to England, when Carrara marble was shipped from Leghorn first to Sicily and thence to England under the above *alias*.

The marble beds of Carrara worked by the Romans are those of Ravaccione, Canal Grande, and Fantiscritti, chiefly for colossal statues, columns, and other

By far the largest proportion of marble in the Carrara division—the principal quarries of which are shown in the plan, Fig. VI—is the common white, the bianco chiaro, and the semi-statuary, the latter being used for colossal statues and columns exposed to the action of the atmosphere.

The finest statuary marble—the *statuario* proper—distinguished alike by its intense cream-colour, its transparency, its homogeneous but not too crystalline grain, its bell-like sound under the hammer, and the ease of being worked with the chisel, occurs only in smaller masses, yielding comparatively small blocks for the finest sculptural purposes. In the Massa division, statuary marble only occurs in one locality, at Bottecini, near Forao, in the Frigido Valley, but the lenticular mass is depreciated by chloritic veins. The ordinary white marble of that division, in the Rosceto and Renara valleys, is less pellucid than that of Carrara, but more fine-grained, and distinguished by its peculiar pearly lustre, albeit with a tendency to become too dolomitic in contact with the underlying grezzoni. It also forms occasional small cavities containing bright quartz crystals known as *stelle*, or stars. To the same category belong the marble beds of the Arni, Sumbra, and Tambura zones, while the great mass of the Monte Altissimo, Giardino, and Falcovaja zone in the Seravezza division is in all respects fully equal to the best ordinary, bianco chiaro, and finest statuary marble of Carrara. Similar to this is the Monte Corchia marble (Fig. III) of the Stazzema division, in which latter also occur considerable masses of fine breccia. The isolated beds of the Seravezza division are all composed of a common, very resistant, bluish-white marble, with occasional dark veins, together with fine blue and veined bardiglio, which equals that of the Para bed of Carrara. Near Colonnata, Carrara, there also occurs a peculiarly black saccharoidal marble associated with the lower grezzoni, the dark colour being probably due to organic impregnations. The *pietra bianca* of Stazzema—as distinguished from marble proper—is a semi-crystalline cipollini variety and, like grezzoni (from *grezzo*, coarse, with rhomboidal fracture), a so-called 'bastard' marble.

Very characteristic is the frequent graduation of ordinary white and bianco chiaro marble into statuary, and vice versa, in the contact and alternation zones of the underlying grezzoni, where rows and patches of so-called *madrimacchie*, or mothermarks, faintly indicate the former lines of stratification obliterated by the action of metamorphism. These brown or ochre marks are obviously impurities infiltrated from the adjoining grezzoni and precipitated by the saccharoidal marble during crystallization, a process which imparted to the statuary marble its high degree of purity. In contact with the overlying nodulous limestone, cavernous grezzoni, or with cipollini, the passage is effected by alternating bands, and the same applies to the contact with bardiglio, which latter alternates with white marble until one or the other predominates. Again, in contact with the

monoliths. The Altissimo quarries and a road of access were opened in 1518 by Michelangelo, whose modest little cottage is still to be seen at Seravezza with the incisive inscription put by himself: "In questa casa abitò Michelangelo Buonarotti per domar le asprezze di questo paese."

upper schists, the white marble shows thin streaks of talcose, lustrous mica, and the same is the case in the veined and breccia varieties. The violet-veined marble called *paonazzi* owes its delicate violet tint to streaks of minute oligist and pyrite crystals. The breccia of the metalliferous Stazzema division also exhibits mineral and micaceous streaks, while the bright-red, wavy marks are due to infiltrations of iron.

Statuary marble, graduating from grezzoni below to ordinary white and bianco chiaro above, occurs in inconsiderable depth more or less in all the principal Carrara quarries from Piastra to Ravaccione, Canal Grande, Fantiscritti, Fontana, Colonnata, and Gioja, while the most abundant and celebrated, because purest and most durable *statuario* occurs in the Polvaccio, Crestola, and Betogli quarries of the Carrara, and in the Altissimo and Falcovaja quarries of the Seravezza divisions.

The most striking and conclusive phenomenon in relation to the statuary marble is that, apart from the lower zones of the marble beds, it occurs also in the very heart of ordinary white marble. This is conspicuously the case in the Polvaccio quarry already mentioned, where the finest *statuario* forms the nucleus of the saccharoidal mass, and gradually passes into ordinary white marble, the latter being here, as the equivalent of madrimacchie, marked by a zone of dusty dark streaks, and hence termed *macchiato*. The intimate association of statuary and ordinary marble is thus conclusively demonstrated.

There is throughout the marble beds in their different varieties and gradations no faulting, nor any evidence of crushing, which, if it existed, would of course render the marble industrially worthless. So far from the marble beds being in any way associated or contemporaneous with the older schists, they form one and all an integral part of the Triassic series which, from the principal grezzoni zone to the upper schists, in stages of metamorphism varying according to the effect of pressure and high temperature upon the original rock material, constitute the lower Mesozoic formation of the Apuan Alps.[1]

REVIEWS.

I.—The Pliocene Mollusca of Great Britain, being Supplementary to S. V. Wood's Monograph of the Crag Mollusca. By F. W. Harmer, F.G.S. Palæontographical Society's Monograph, 4to, 1914, pp. 201–302, pls. xv–xxxii.

IN the year 1847 the Palæontographical Society issued its first annual volume, consisting only of Part I of the *Crag Mollusca*,

[1] The evidence adduced in this paper is wholly adverse to the view recently expressed by Professor Bonney in this Magazine (July, 1915, p. 294) that the schists and marbles of Carrara are most probably of Archæan age.

An additional feature of interest in the Apuan Alps is the evidence of former glaciation. Stoppani, as early as 1872, was the first to point out a detritus cone of striated material at the lower end of the Arni Valley (R. Inst. Lomb. Sci. Nat., vol. v, p. 733; also Atti Soc. It. Sci. Nat., Aprile, 1875). Similar deposits occur at high levels in the Carrara valleys and on the slopes of Pisanino, Sumbra, and Corchia: and Zaccagna met with conspicuous *roches moutonnées* on a calcareous schist ledge in the Granolazzo (Upper Serchio) Valley, about 50 metres in length. A more detailed notice of these glacial phenomena would exceed the scope and limit of the present paper.

Univalves, by Mr. S. V. Wood. In the intervening years no fewer than sixty-seven large quarto volumes, rich in illustrations, have gone forth, each containing parts of numerous important monographs, but until the appearance of the sixty-eighth volume the publication of only one author's work has never been repeated. It is a sign of the times, indeed, when this single part represents the total issue of the past year's labours.

The present instalment of this valuable Supplement to Mr. S. V. Wood's *Crag Mollusca* continues the tale of the first part (noticed in the Geological Magazine, 1914, p. 227) and deals with the difficult group of the Pleurotomidæ.

Since the author, as he explains in his preface, has "followed, more or less nearly, for the convenience of students, the arrangement of the Marine Mollusca adopted by him [S. V. Wood]", the new Supplement to the very much earlier monograph, while adding greatly to the value of Mr. Wood's work, will not, we fear, satisfy entirely the more exacting and critical systematists of to-day, despite the manifest care and pains bestowed upon it. No captious criticism, however, can be applied to the plates, which are far and away the best molluscan illustrations the Society has ever published, and impress one at once as being really like the objects they represent, so that altogether the student cannot fail to recognize the forms dealt with, whilst the introduction of figures of recent species for comparison with the fossil forms is a wise and very helpful course, and cannot be too strongly commended to biologists in other groups, whose labours enrich this Society's publications from year to year.

II.—A Description of the Sub-Crag Detritus-Bed. By A. Bell. Proceedings of the Prehistoric Society of East Anglia, vol. ii, pp. 139–48.

THE pursuit of the *ignis fatuus* of pre-Crag Man has not been without some useful results for the palæontologist, since the recent borings have enabled the author of this note to bring together a most useful summary of the latest facts concerning the sub-Crag detritus-bed.

This bed, first brought to the notice of geologists by Professor J. S. Henslow in 1843, is made up of the following constituents: (1) Phosphatic nodules (the so-called Coprolites), (2) sandstone nodules or box-stones, (3) rocks of various ages earlier than the Crag, (4) large chalk flints, many unrolled, (5) rolled and water-worn bones, usually much mineralized, (6) Cetacean beaks (rostra), and other bones, (7) bones and teeth of land mammalia, (8) wood and other items, chiefly of uncertain age. These groups belong to very different periods and are not of equal value numerically. The phosphatic nodules have yielded some twenty species of Chelonia, Pisces, and Crustacea, all of Sheppey types. The box-stones, the author considers, present in their fauna hardly any elements in common with the Diestian, to which they have been referred. The list of fossils contains eighty species of the more characteristic shells of the Oligocenes of North Germany, Belgium, and Denmark, but the

facies suggest to Mr. Bell a later date, somewhat nearer Miocene times.

How some of the rocks came into the area is an unsolved question, as also the exact type and horizon of the flints. The age of the rolled and mineralized bones, both of whales and land mammalia, whether Pliocene or Miocene, is still considered doubtful, and the author concludes by damning with faint praise the alleged pre-Crag occurrence of Man.

III.—A Contribution to the Knowledge of the extinct Sirenian *Desmostylus hesperus*, Marsh. By O. P. Hay. Proc. U.S. Nat. Mus., vol. xlix, p. 381, pls. lvi–viii.

THE remarkable Sirenian which forms the subject of this paper was originally described in 1888 by Marsh, who with very fragmentary material at his disposal was nevertheless able to determine its affinities with accuracy, as is clearly proved by the specimen now discussed. This consists of the greater part of a skull wanting a portion of the snout and some other parts. Some of the peculiar teeth are *in situ*. The skull differs from the usual Sirenian type (1) in having the snout only slightly deflected and (2) in having the narial opening comparatively small and far in advance of the orbits. The teeth are extremely hypsodont, and are composed of rows of cylindrical columns closely crowded together. Their peculiar character led Yoshiwara and Iwasaki, who described a closely allied but larger species from Japan, to regard the animal as probably Proboscidean. The two species, *Desmostylus hesperus*, Marsh, from the Western States of America, and *D. watasei*, Hay, from Japan, are of Miocene age.

IV.—The Fauna and Stratigraphy of the Kent Coal-field.

MR. HERBERT BOLTON has recently issued a paper on the above subject (Trans. Instit. Mining Engineers, vol. xlix, pp. 643–702, pls. vii–ix, 1915), which had been previously read before the Manchester Geological and Mining Society. His researches contain the results of an examination of a large series of Coal-measure cores from the Kent Coal-field, obtained from localities lying within "a triangular area, bounded by the coast-line from Dover to Ramsgate on the east, by the Dover to Canterbury road on the south, and by the railway line from Canterbury to Ramsgate on the north". The Carboniferous Limestone floor was reached at depths varying from 3,185 feet at Bourne to 1,149 feet at Ebbsfleet, whereas the Coal-measures were proved to exist in other parts of the region investigated at considerable depths without striking the Carboniferous Limestone, as for instance at Maydensole, where they were pierced at 3,512 feet below Ordnance Datum. The author gives important generalized sections of all the borings undertaken, including carefully determined fossils found in each, with ample notes on the species, the whole fauna being tabulated for comparison with that of the Somerset and Bristol Coal-fields. He refers to a difference of opinion between himself and Dr. Arber as to the presence or otherwise of

Lower Coal-measures in the Kent Coal-field. From his studies of the fossil flora of the region, Dr. Arber has been unable to recognize the existence of the older Coal-measure Series, whereas the author states that the occurrence of *Lingula*, *Orbiculoidea*, and *Productus* conclusively proves the opposite view, he being also of opinion that a fauna furnishes more reliable data as "determinants of the age of the beds" than the flora. The palæontological evidence is considered to support Marcel Bertrand's theory "of a formerly continuous coal-field stretching from South Wales on the west, through Bristol and Somerset into Kent, and thence eastwards to the Pas-de-Calais of Northern France and Belgium". A plate of fossils and diagrammatic sections of the various borings add to the great interest of the memoir, among the former being illustrations of *Prestwichia anthrax*, different forms of *Anthracomya*, *Naiadites carinata*, *Lingula mytiloides*, *Orbiculoidea nitida*, *Productus scabriculus*, *Cœlacanthus elegans*, etc.

R. B. N.

V.—A peculiar Oolite from Bethlehem, Pennsylvania. By Edgar T. Wherry. Proc. U.S. Nat. Mus., vol. xlix, pp. 153–6, pls. xl, xli, 1915.

THE oolite described occurs in magnesian limestone of Upper Cambrian age, and is chiefly remarkable for the fact that, except in the centre of the blocks formed by bedding and joint-planes, the grains are divided equatorially into upper light and lower dark portions. They are composed of dolomite of purer consistency than the matrix, and the darkness of the lower halves is due to carbonaceous matter.

The author's explanation is as follows:—"When the ooids [oolitic grains] were first formed they no doubt consisted of aragonite, whereas the matrix was dolomite-mud. Mixed with the aragonite, in varying amounts in the different concentric layers, was the carbonaceous pigment. After the solidification of the sediment into rock and the development of joint cracks (but before the uptilting of the beds) waters penetrated along these cracks and along the bedding planes. Since aragonite is more soluble than the dolomite of the matrix, it dissolved away, leaving behind the carbon and the nuclei—sand grains and bits of kaolin—in some cases stripped of all concentrically deposited aragonite, in others still retaining a few layers. These settled to the bottom of the cavities in heaps, the shapes of which varied with the sizes of the nuclei and the stage of solution process at which they fell into the masses of carbon powder.

"At some later period water again traversed the rock, but this time conditions were favourable to deposition instead of solution, and secondary dolomite filled up all openings in the rock, tension and joint cracks as well as the holes left by the removal of the ooids . . . The secondary crystallization took place so slowly and quietly that the heaps of carbonaceous dust were not disturbed, but merely enclosed by the crystal grains, and their shapes preserved."

VI.—Fauna of the Wewoka Formation of Oklahoma. By George H. Girty. Bulletin 544, Department of the Interior United States Geological Survey (George Otis Smith, Director), 1915. pp. 353, with 35 plates.

IN this memoir the author makes some interesting preliminary remarks on the duties of the palæontologist, whom he regards as a biologist and a stratigrapher. He states that "the stratigraphic palæontologist, or, as he might be called, the stratilogist, is not primarily concerned with the delineation of geologic formations on a map . . . his special task is the correlation of formations that are geographically separated". He is of opinion that a fauna should be fully described and figured, and not listed as is often done, which is "in effect to state conclusions without producing evidence". The Wewoka formation belongs to the Carboniferous system, its faunistic facies suggesting an early stage of the Pennsylvanian series as well as exhibiting some striking resemblances to certain fossils from Kansas of about the horizon of the Fort Scott Limestone. Most of the zoological groups are represented in this fauna, the Mollusca being numerically greater than the Brachiopoda. The Foraminifera (*Fusulina*), Sponges, and Crinoidea are more or less rare, whereas among the Corals *Lophophyllum profundum* is said to be of abundant occurrence. Nearly 150 species or forms are described and figured, an account of the more important genera being also added. The work has been carefully prepared, and is a valuable addition to the history of an extremely interesting Palæozoic fauna.

R. B. N.

VII.—Fauna of the San Pablo Group of Middle California. By Bruce L. Clark. Bull. Dept. Geol. Univ. California Public, 1915, vol. viii, No. 22, pp. 385–572, pls. xlii–lxx (chiefly Mollusca) and pl. lxxi (map).

THE author's researches on this series of Tertiary rocks have resulted in the San Pablo Beds being recognized as a 'group' rather than a 'formation' as originally described by Professor J. C. Merriam, and representative of the Middle Neocene. From a study of the fauna, the San Pablo group of Middle California is made divisible into two major zones which are quite distinct, as shown by the molluscs and echinoderms, both zones being again split up into minor faunal zones, which are indicated by the restricted range of echinoderm species, as also of molluscan species. Although mostly of marine origin, it is ascertained that the San Pablo deposits exhibit at different levels certain estuarine and brackish-water conditions. Many of the extinct species are related to forms living off the present-day Californian coast (= Pacific). The author is further of opinion that the San Pablo group is of Upper Miocene age.

The described fauna includes 9 extinct species of Echinodermata; 3 Bryozoa; 3 Crustacea; 86 Pelecypoda, of which 55 are extinct, 27 recent, and 29 new; 62 Gastropoda, embracing 46 extinct, 9 recent, and 33 new; and 1 Scaphopoda. This memoir is planned out with great care and detail, every information being given in connexion with the stratigraphy and lithology as observed at the

various localities, together with well drawn up faunal lists. Correlation data, a bibliography, and well-executed plates stamp the whole work as a contribution of considerable importance to our knowledge of Californian Tertiary palæontology.

R. B. N.

VIII.—Brachiopod Genera: the Position of Shells with Magaselliform Loops, and of Shells with Bouchardiform Beak Characters. By J. Allan Thomson. Trans. New Zealand Inst. 1914–15, vol. xlvii, pp. 392–403, with text illustrations.

As indicated by the title, this paper deals with the evolutionary characters as observed in the loop and hinge structures of certain Brachiopod shells. The Terebratelliform type is discussed with special reference to *Terebratella sanguinea* of Recent seas. Then follow remarks on the Pachymagoid and Neothyroid types, illustrations being given of the cardinal process in *Pachymagas parki* (Hutton), *P. huttoni*, sp. nov., *Neothyris ovalis* (Hutton), all from the New Zealand Tertiaries; and *Neothyris lenticularis* (Desh.) of recent habitat. The author then describes the new Miocene genus *Magella*, which possesses a Terebratelliform hinge and a Magaselliform loop, based on what he formerly determined as *Terebratella kakuiensis*, but which on account of the specific name being preoccupied is now changed to *Magella carinata*. Shells with Bouchardiform beak characters are next discussed, there being certain New Zealand Miocene (Oamaruian) forms described by Hutton, as *Bouchardia rhizoida* and *B. tapirina*, which while possessing Bouchardiform beaks are furnished with Magellaniform loops and septa; for the reception of such the author proposes the new genus *Rhizothyris*, the selected genotype of which is Hutton's *Bouchardia rhizoida*. Some shells are said to be provided both with Magaselliform and Terebratelliform loops, but showing Bouchardiform beak characters and contour, and for these is established the new genus and species *Magadina browni*, from the Mount Brown Beds of North Canterbury. Another new genus is described as *Magadinella* on Tate's type of *Magasella woodsiana*, in which the beak characters are not strictly Bouchardiform, although bearing considerable external resemblance to *Magadina*, but with a more advanced loop structure than that genus and representing an early Terebratelliform stage.

R. B. N.

IX.—Revision of the Tertiary Mollusca of New Zealand, based on Type-material. Part II. By Henry Suter. Palæontological Bulletin, No. 3, New Zealand Geological Survey (P. G. Morgan, Director). 4to; pp. 69, with 9 plates, a transmittal letter by P. G. Morgan, and a preface by Henry Suter. Wellington, 1915.

The first part of this monograph, which was issued last year and of which a review has already appeared (Geol. Mag. 1915, pp. 374–5), comprised a revision of the molluscan species described in the late Captain F. W. Hutton's *Catalogue of the Tertiary*

Mollusca and Echinodermata of New Zealand in the Collection of the Colonial Museum, published in 1873. The present fasciculus embraces further revision work of New Zealand Tertiary shells described subsequently to 1873 by the same author, and which are said to be preserved in the Canterbury, Otago, and Geological Survey Museums. Mr. Suter also furnishes redescriptions of six species of the Hutton Catalogue, besides including some notes on other molluscan types established by Kirk, Hector, E. de C. Clarke, P. Marshall, and J. Allan Thomson. He recognizes rather more than a hundred species of Gastropoda and about forty Pelecypoda, among them being the following new forms: *Struthiolaria parva*, *Turris* (*Hemipleurotoma*) *nexilis*, Hutton, sub-species *bicarinatus*, and *Trigonia neozelanica*. The whole of the species, as in part i, belong to rocks which are regarded as either of Miocene or Pliocene age. As this completes the author's researches on the type-material of New Zealand Tertiary Mollusca, we heartily commend its results to all students of palæoconchology, as well as to those interested in problems connected with the ancestry of present-day shells common to New Zealand seas.

R. B. N.

REPORTS AND PROCEEDINGS.

I.—Geological Society of Glasgow.

At the first meeting of the session of the Geological Society of Glasgow, held on October 14, Professor J. W. Gregory, F.R.S., F.G.S., delivered his Presidential Address on "Geological Factors affecting the Strategy of the War".

The following summary has been issued:—

The geological influences on international politics are less widely appreciated than the geographical, but the War with its new struggles on former battlefields is largely controlled by the geological structure of Europe. The distribution of the mineral resources of the Continent is affecting the course of the War, and may have a still more important bearing on the diplomatic negotiations at its end. The redistribution of political power in Europe during the past forty years has been greatly affected by the discovery that Germany is one of the greatest coal countries of the world. Since 1870 we have increased our coal output two and a half times, and Germany has magnified hers eightfold; and even more significant is the discovery that the German coal reserves are estimated as more than twice as large as our own, and are estimated as 423,000 million tons, out of the 784,000 million tons for the whole of Europe. The significance of that pregnant fact has not been generally recognized. The German coal-fields are all placed in exposed positions near the frontiers, and Germany has therefore maintained an army ready for instant battle. Her military capacity has been illustrated by her seizure of the Belgian, Polish, and chief French coal-fields and successful defence of all her own.

The future of the war-wrecked Galician oil-field affects British interests in opposite ways. The Scottish oil trade would profit if the field were annexed by Russia; but those British industries which need cheap paraffin would suffer by the change. The belief that Germany could not continue the struggle if her imports of copper were stopped was one of the most widespread early illusions of the war. Germany's own copper production would doubtless suffice for her military needs. The total copper production of Germany in 1913 was 25,000 tons, but with a rise in the price of copper the extensive areas of low-grade ores at Mansfeld could be profitably worked.

The great iron ore-field of Lorraine and the recent discovery of the potash mines of Alsace both increase the difficulty of the readjustment of the Franco-German frontier. Germany now obtains three-quarters of her iron-ore from Lorraine and would strenuously resist the loss of that field. The transfer of that area would probably be detrimental to its own economic interests. The re-annexation of Alsace by France offers the best prospect by breaking the German monopoly in the supply of potash. The Americans especially have endeavoured to escape from that monopoly by finding fresh sources of potash and by dodging German restrictions on the output. The German potash fields were formed by such an unusual sequence of geographical events that they are quite unique. It has been calculated that one of the German fields, even with an increased output, will last for 600,000 years. It has been suggested that at the end of the war the German potash mines might be held as security, but they are so widely spread through Western Germany that their military occupation would be very expensive and the total profit from the potash mines would be insignificant in war finance.

II.—Liverpool Geological Society.

The annual meeting of this Society was held on October 19, 1915, the President, Mr. W. A. Whitehead, B.Sc., in the chair. Mr. J. H. Milton, F.G.S., F.L.S., was elected President for the new session, and Dr. J. C. M. Given Vice-President. It is gratifying to record that the Society enters upon its fifty-seventh session with a slightly increased membership and with undiminished vitality.

The retiring President took for the subject of his address "Sandbanks and Sand-dunes". The conditions affecting their formation and growth were discussed in detail, special reference being made to the deposits of the Lancashire coast, which extend twelve miles north of Liverpool and eight miles out to sea. Surface features such as ripple and current marks were then described, and the differences between æolian and subaqueous ripple-marks explained. Finally, the records in the Triassic sandstones were referred to, and compared with the modern deposits. Ripple-marking was a fairly common feature in certain beds of the Trias, and was mostly associated with marl bands, and presumably with shallow water, judging from the proportions of length to height. In fact, most of the positive evidence pointed to local water conditions, and it was not impossible

that as more was discovered about the building of dunes and sand-banks, geologists might be able to decide on inspection whether a false-bedded section represented an æolian or an aqueous deposit.

III.—Geological Society of London.

November 3, 1915.—Dr. A. Smith Woodward, F.R.S., President, in the Chair.

Dr. C. W. Andrews, F.R.S., gave an account of the discovery and excavation of a very large specimen of *Elephas antiquus* near Chatham. The specimen was originally discovered about three years ago by a party of sappers who were digging a trench. The attention of the British Museum was drawn to this find by Mr. S. Turner, of Luton, Chatham. The extraction of the bones was delayed until the past summer. A great part of the skeleton has now been collected, owing largely to the skill of Mr. L. E. Parsons, jun. The skull, unfortunately, was in a very bad condition, but two complete upper and one lower second molars were obtained. One tusk, about 7 or 8 feet long, was also found. The lower ends of both femora were destroyed in the original trench, but of the other limb-bones nearly complete specimens from one or both sides have been obtained, as well as a sufficiently large series of bones of the feet to allow of their reconstruction. Many vertebræ were also collected.

The animal, which was adult, must have been of very large size, having stood about 15 feet at the highest part of the back, or more than 3½ feet higher than the large African elephant mounted in the Entrance Hall of the Natural History Museum.

The molar teeth show conclusively that the species represented is *Elephas antiquus*, and from the thickness of the enamel and some other characters, it may be inferred that the animal was probably of a type as early as, or earlier than, that found at Grays. It is the first British example of this species in which the skeleton has been found directly associated with the teeth.

Lantern-slides and remains of *Elephas* were exhibited.

Mr. G. C. Crick, F.G.S., exhibited two Nautili from the Upper Cretaceous rocks of Zululand. Each showed approximation of the last three septa, indicative of the comparatively sudden arrest of growth of the animal and of the accompanying forward movement of the animal in its shell, a character usually attributed to senility. One specimen showed also irregularities of depth in the other chambers of the camerated part of the shell.

CORRESPONDENCE.

EARLY MAN AND HIS IMPLEMENTS.

Sir,—With reference to Mr. Reid Moir's letter in the October Number of the Geological Magazine criticizing M. Boule's recent paper in *Anthropologie*, the Abbé Breuil requests me to ask you, on his behalf, the favour of publication of the following remarks, and copy of his letter to me of February 27, 1913.

"PARIS, *Oct. 29, 1915.*

"I ask this publication relying on my right of reply, since I deem it beneath my dignity and scientific repute to reply directly to the poor and arbitrary attack of Mr. Reid Moir against my scientific independence and experience. — H. BREUIL."

49 QUEEN VICTORIA STREET, E.C. F. N. HAWARD.
November 2, 1915.

[COPY.]

"110 RUE DEMOURS, PARIS.
February 27, 1913.

"DEAR MR. HAWARD,—I am entirely of your opinion concerning the so-called Pre-Palæoliths (or 'Eoliths') of Mr. Reid Moir and Sir Ray Lankester. Your article[1] is very strong against them, but, as with all their 'Eolithic-loving' confrères, it is difficult to discuss with these gentlemen. They affirm their opinions with too much enthusiastic conviction, which prevents them from appreciating the rights of others to doubt.

"The 'Eoliths' of the Pre-Crag bed of these gentlemen are really much older than the deposit which contains them; probably they came from the remains of Miocene or very old Pliocene, or of beds of the sort you have described. If they had been chipped by intelligent beings, it would not have been during the Pliocene period, but at a period too early for the probable geological antiquity of mankind, because it would be necessary equally to admit not only Le Puy Courny (Miocene) but Boncelles, which is at least Oligocene. Now at Boncelles M. Rutot has discovered at the side of his so-called 'human station' a spot yielding similar flints to those of Belle Assise, but much finer, resulting evidently, even in his opinion, from movement of the soil.

"I have brought to these gentlemen the best flints from Belle Assise. Mr. Reid Moir would not say that these were not made by Man. Sir Ray Lankester was more prudent: he said 'that they were not due to pressure'. I replied that in any case the fracture and the 'retouching' were produced after they were embedded in the Eocene sand. 'Sand like water produces nothing by pressure,' so far as static pressure is concerned, but movement of the soil, as you say so well, produces formidable compression.

"There are some who believe that two or three laboratory experiments are equivalent to the mechanism so complicated and so varied as is that of Nature. There are experiments that one cannot reproduce in the laboratory, and others which are not worth the trouble, or which would cost too much to demonstrate an evident thing. And yet these gentlemen say that it has been done by machinery, and that consequently this proves nothing (as in the case of Mantes).

"When one examines the geological formation of the 'Sub-Crag beds', where one finds the so-called 'Rostro-Carinates' and accompanying flints, it is striking that in all the pits where they can be seen one always finds them infallibly and abundantly. This fact is evidence that one is in the presence of a *geological and not an archæological phenomenon*. Also, there are many other flints in these beds besides those which have been presented as 'humanly worked'; some show no fracture, others one or two or a few fractures without signification, others are doubtful, although more elaborate in appearance, even in the opinion of the enthusiasts. Others carry written on their facets and edges the history of their long misadventures; the 'patina' of the facets proves the repeated action by the mechanical forces which is convincing to unbiassed minds well disposed to discuss dispassionately.

"Probably there was a relation of 'cause and effect' between the production of scratches and the chipping of the edge of the opposite side. One would say

[1] "F. N. Haward, 'The Chipping of Flint by Natural Agencies': Proc. Prehistoric Soc. E. Anglia (read December 4, 1911)."

the flints were fixed in such a manner that a moving mass of ice or earth slipped over, scratching the upper face and 'retouching' the opposite.

"One can often see that the predominating direction of the scratches is almost normal at the chipped edges. Sometimes it is evident that the hard substance which has incised a deep scratch has also dug, in some place where its action has been prolonged, a little 'cupola of contusion'. Later the line was continued as far as the more fragile edge, where the flint breaks, giving a bunch of chips on the other side, thus *simulating a concave scraper.*

"These explanations account for most of the so-called 'worked flints' of Pre-Crag beds and are very like those which you proposed. But it is astonishing that to obtain a good type of 'rostro-carinate' or similar 'implements' so many renewals of chipping of very different ages were necessary.

"So it seems some of the chipped facets can be Eocene, and the continuation of the same working could be Miocene or Pliocene. In any case, the difference of the age between the successive chippings is so great that it excludes the probability of the work of man. Otherwise very different actions seem to have collaborated. Probably in the first bedding of these flints there was the same compression as at Boncelles and Belle Assise; afterwards they were transported by diverse forces (more or less violent) which have left sometimes traces extremely energetic. Others, specially, more or less deeply graven lines, generally limited to one side, are to be considered. Often the other side is similarly favoured by abundant 'retouching'.

"I believe it is necessary to exercise very great caution and possess much familiarity with both 'natural' and 'artificial' chipping of flint to enable one to distinguish the difference. In many cases the natural fracture gives the same appearance as the rough working and chipping of Man. So it is sometimes impossible to distinguish between the work of Nature or Man, and the proof will come from another source than the morphology, which is too deceitful, because the natural inclination of the human imagination is towards the 'morphomanic'.

"*As to the Ipswich skeleton*, I think that it is senseless to present it as 'Pre-Glacial'. The superdeposited soil is evidently due to the alteration and transport of Boulder-clay down the slope. It is not Boulder-clay, it is a dateless deposit (limon). The body had the position of a buried person, fairly old, perhaps Neolithic. A grave dug in non-stratified soil would not have left any trace after a considerable time. The decalcified soil of the clay and of the grave ('Middle Glacial') would not have permitted the preservation of a body so old at such a shallow depth.

"Finally, the position of the body is absurd. If the body had been abandoned on the seashore it would have been dismembered, and the bones would have been separated, rolled, destroyed. If the body is later than this marine plateau (and it is, since it is partly in the overlying bed), then it dates from this later bed; but if so, if it was a 'moraine de fond', the man could not have been precipitated into it, neither dead nor alive, and a body on the shore of the Middle Glacial sands would have suffered terrible injuries from the glacier. The bones would have been crushed, disjointed, and dissolved by the waters of the glacier.

"All this is incomprehensible on the hypothesis of Mr. Moir, and, on the contrary, is amply explained by yours and mine—burial in date probably late prehistoric, in a modern soil derived by means of the alteration and the reshuffling of the chalky Boulder-clay.

"H. BREUIL."

THE ALKALINE ROCKS OF SOUTH-WEST AFRICA.

SIR,—Since reading Mr. Holmes' paper on the alkaline rocks of Angola (GEOL. MAG., July and August, 1915) I have thought that a brief note on the somewhat similar rocks occurring near Pomona and in Namaqualand may be of immediate interest. I received a collection of these rocks from Dr. A. W. Rogers in 1914, and I intend to visit

the localities myself to make a fuller study than is possible in the laboratory. In the meantime the following notes may be of interest.

The nephelite-syenite of the Granitberg was described very briefly by Wagner. It is a foyaite with a very variable amount of nephelite, which may locally make up two-thirds of the rock. The chief dark mineral is a green ægirite-augite. This rock is cut by two dykes of a singularly interesting microfoyaite which contains, in addition to microperthite, nephelite, and pyroxene, smaller amounts of biotite, perovskite, and zircon. The perovskite forms perfect octahedrons up to half a millimetre in diameter. Zircon occurs in skeletons and irregular groups and plates, and often encloses grains and laths of felspar. The dark minerals amount to just under 10 per cent of the rock.

From the neighbourhood of Pomona there are several monchiquites and camptonites, some fresh and others too much decomposed for certain identification. In one of the camptonites, crystals of barkevikite are enclosed by titanaugite with a reaction rim of magnetite separating the two. In all these lamprophyres there are pseudomorphs of a mineral like iddingsite, apparently replacing olivine. I have also a beautiful ægirite-solvsbergite with marked flow-structure, and some typical bostonites and lindöites. Dr. Rogers has also found numerous bostonite dykes in Van Rhyn's Dorp and Namaqualand.

I hope to publish a full account of these interesting rocks in the course of time.

S. J. Shand.

Geology Department, Victoria College,
Stellenbosch, S.A.

October 1, 1915.

BURSTING OF A LAKE BARRIER IN ARGENTINA.

Sir,—It is not often that one finds anything of geological interest in the report of a railway company, but the following details from the Report of the Directors of the Buenos Ayres Great Southern Railway Company for the year ended June 30, 1915, are interesting.

"The most sensational, although by no means the most costly, of the long series of mishaps due to this cause [the weather], was the cataclysm in the Rio Colorado Valley in the early days of January, when some thirty-six miles of the Railway were submerged under deep water, and traffic on the Neuquen line beyond Gavietas was entirely cut off for almost a month. This stupendous, and at first inexplicable visitation, was discovered to be the outcome of the sudden release, 350 miles away from the line as the crow flies, of an immense body of water called Lake Carrilauquen, which had been formed by a landslide at a comparatively recent geological epoch. Owing to stress of weather this natural dam suddenly gave way and thus launched 2,800,000,000 tons of water into the valley of the Rio Colorado."

The lake is nearly 6,000 feet above the sea-level. It was some 15 miles long, 1¼ miles wide, and over 300 feet deep at the lower end.

Bernard Hobson.

INDEX.

ABEREIDDY and Abercastle, Geology between, 94.
Acmæa, Early Stage of, 41.
Ægirine-Riebeckite Granite, Lower Congo, 267.
Ætheia gen. nov., J. A. Thomson, 389.
Alkaline Rocks of South-West Africa, 575.
Alpine, Lowland, and Jura Lakes, Switzerland, 343.
Andalusite and Chiastolite, 336.
Anderson, E. M., Pitchstones of Mull, 138.
Anderson, William, Obituary of, 476.
Andrews, C. W., Skeleton of *Ophthalmosaurus icenicus*, 145; Skeleton of *Myotragus*, 338; Fore-paddle of *Metriorhynchus*, 444; on *Elephas antiquus*, 573.
Angola, North-Western Petrology of, 228, 267, 367.
Anticosti Island Faunas, 84, 379.
Antiquity of Man, British Geological Evidence, 470.
Appleby District, Geology of, 431.
Apractocleidus, gen. nov., W. R. Smellie, 341.
Apuan Alps, Carrara Mountains, 289, 554.
Argentina, Bursting of Lake Barrier, 576.
Arizona, Grand Gulch Mining Region, 42.
Ashgillian Succession, West Coniston, 187.
Assynt Mountains, Geological Model of, 280.
Asterozoa, Comparison with Edrioasteroidea, 316.
Australia, South, Oil Report, 428.

BARNSLEY Coal-seam, Contours of, 465.
Barshaw, Bekinkinite and other Rocks of, 304, 361.
Bather, F. A., Studies in Edrioasteroidea, 5, 49, 211, 259, 316; Morphology and Bionomics of Edrioasteridæ, 211, 259.
Beatricea, 379.
Beauly and Inverness, Geology around, 330.
Bekinkinite of Barshaw (Renfrew), 304, 361.
Bell, A., Molluscan Deposits of Wexford and Man, 164; Sub-Crag Detritus-Bed, 566.
Beyschlag, F., Useful Minerals and Rocks, 177.
Bionomics of Edrioasteridæ, 211, 259.
Bolton, H., Kent Coal-field, 567.
Bone Implement, Piltdown (Sussex), 45.
Bonney, T. G., Geological Age of Carrara Marbles, 289; Charnwood Forest, 545.
Bore at Seascale, Cumberland, 146.
Boswell, P. G. H., Tertiary Differential Movement in East Anglia, 198; Stratigraphy and Petrography, London Basin, 234; Petrology of Suffolk Box-stones, 250.
Boule, M., Human Palæontology, England, 429.
Boulenger, E. G., Reptiles and Batrachians, 38.
Box-stones, Suffolk, Petrology of, 250.
Brachiopod Genera, 570.
—— Morphology, 71.
Brammall, A., Intrusive Rock, Marston Jabet, 152; Genesis of Chiastolite, 224.
Breuil, H., Early Man, 574.
Brighton, *Marsupites* Chalk, 12.
British Association, Manchester, List of Papers read in Section C, 464, 520.
British Borneo, Tektite from, 206.
British Museum (Natural History), Return, 87.
Brooks, C. E. P., Zones of Chalk, Middlesex, 238.
Brydone, F. M., *Marsupites* Chalk, Brighton, 12.
Burling, L. D., *Albertella* Fauna, Canada, 42.

CAITHNESS, Geology of, 279.
Callaway, Charles, Obituary of, 525.
Camel Remains, Alaska, 41.
Canada Department of Mines, Geological Survey, 84, 136.
Carbonaceous Zones, Lancashire, 521.

Carboniferous Aerolite, Rajputana, 89.
Cardiff, Silurian Inlier near, 386.
Carrara, Massa, and Versilia Marble District, 554.
Carrara Marbles, Geological Age of, 289.
Charixa, gen. nov., W. D. Lang, 500; *Ch. vennensis*, gen. et sp. nov., W. D. Lang, 501.
Charnwood Forest, 545.
Cheilostome Polyzoa, New Uniserial Cretaceous, 496.
Chiastolite, Genesis of, 224.
Cirripedia, Wrongly Classified, 112.
Clark, B. L., Fauna of San Pablo, 569.
Clarke, F. W., Crinoids and Dolomite, 40.
Classification of Land Forms, 472.
—— of Trilobites, 487, 538.
Coal Resources of Korea, 89.
Coal-field, Kent, 567.
Coal-measures, Clapton, Somerset, 312.
—— S. Lancs, Marine Band in, 311.
Coast Erosion, Sidestrand, Norfolk, 476.
Coastal Series of Sediments, E. Africa Protectorate, 274.
Cole, G. A. J., Composite Gneiss, Barna, Galway, 283.
Coleman, A. P., Radio-activity and Earth's History, 273.
College Physiography, 82.
Composite Gneiss, Barna, Galway, 283.
Cone-in-Cone Structure, 92.
Coniston Grits, Windermere, 169.
Cox, A. H., Pembrokeshire Geology, 94.
Crag (Sub-) Detritus-Bed, 566.
Crampton, C. B., Geology of Caithness, 279.
Crawfordjohn Essexite, 455, 513.
Crewdson, Canon, Coniston Grits, Windermere, 169.
Crinoids and Dolomite, 40.
Cryptophragmus, 85.
Crystallization of Silicate Mixtures, 376.
Cumberland, near Solway, Geological Structure of, 410.

DALL, W. H., Oligocene Mollusca, Florida, 428.
Danbury Gravels, 529.
Dawkins, W. Boyd, Antiquity of Man in Britain, 470; Classification of Eutherian Mammals, 520.
Dawson, C., Bone Implement, Piltdown, 45.
Day, A. L., Water and Volcanic Activity, 175.
Day, H., Derbyshire Limestone, Fauna of, 467.
Deeley, R. M., Polar Climates, 450.
Derbyshire Limestone, Fauna of, 467.
Desmostylus hesperus, Marsh, extinct Sirenian, 567.
Dewey, H., Geology of Windsor and Chertsey, 232.
Differential Movement in East Anglia in Tertiary Times, 198.
Directions, Image of Mineral, Isolation of, 473.
Distelopora bipilata, gen. et sp. nov., W. D. Lang, 503.
Dixey, F., Coal-measures, Clapton, Somerset, 312.
Drainage Area, River Tyne, 294, 353.

EALING Scientific Society, 87.
Early Man, 573.
Earthquakes in Burma, 377.
Earth's Thermal History, 60, 102, 273.
East Africa, Coastal Series of Sediments, 274.
East Anglia, Tertiary Differential Movement in, 198.
East Anglian Prehistoric Society, 522.
Edinburgh Geological Society, 95.
Edrioasteroidea, Studies in, 5, 49, 211, 259, 316, 393, 478.
Electric Activity in Ore-deposits, 137.
Elephas antiquus, 573.
Eminent Living Geologists: Strahan, A., 193; Watts, W. W., 481; Woodward, A. S., 1.
Engineering Geology, 85.
English Glacial Epoch, 418, 434, 504.
Essex Gravels, Composition, 534.
Etheridge, R., Gingin Chalk, West Australia, 41.
Eutherian Mammals, Classification, 520.
Evans, J. W., Directions Image of Mineral, 473.

FALCONER, J. D., Classification of Land Forms, 472.
Fauna of Hydraulic Limestone, South Notts, 150.
—— San Pablo, California, 569.
Fearnsides, W. G., Barnsley Coal-seam, 465.
Ferberite in Colorado, 378.
Fermor, L. Leigh, Laterites of French Guinea, 28, 77, 123.

Fernando, Fossiliferous Sandstones, 90.
Flints from Suffolk Bone Bed, 191.
Fossil Mammals, Sebastopol, 89.
—— Remains of Man, Guide to, 129, 191.
Fossiliferous Horizon, Coniston Grits, 169.

GARDINER, C. I., Silurian Inlier of Usk, 91.
Geikie, J., Obituary of, 192.
Genesis of Chiastolite, 224.
Genetic Relations of *Edrioaster*, 393.
Geological Society, Edinburgh, 95, 189.
—— Glasgow, 236, 285, 571.
—— Liverpool, 96, 190, 237, 572.
—— London, 44, 90, 91, 93, 137, 180, 187, 188, 234, 282, 283, 284, 334, 573.
—— Survey, Great Britain, Memoirs, 171, 232.
—— —— Ireland, 431.
—— —— New Zealand, 570.
—— —— Scotland, Memoirs, 279, 281, 330.
—— —— South Africa, 384.
—— —— South Australia, 428.
—— —— Southern Rhodesia, 430.
—— —— United States, 38, 89.
—— —— Western Australia, 430.
Geologists' Association, 43, 95, 189, 384.
Geology, Department of, California, 90.
—— and War, 571.
Gilbert, G. K., Transportation of Debris by Water, 132.
Gilmore, C. W., New Restoration of *Stegosaurus*, 525.
Girty, Wewoka Formation, Oklahoma, 569.
Glacial Geology, South Pennines, 468.
—— Period, England, 418.
Granite Rocks of Lake District, Accessory Minerals, 334.
Graphite, Production of, 1913, 136.
Gravels, Danbury, Essex, 529.
—— of East Anglia, 137.
Gregory, J. W., Deep Bore at Seascale, 146; The Solway Basin, 241; Moine Pebbles in Torridonian Conglomerates, 447; Danbury Gravels, 529; Geology and War, 571.
Grimes Graves, Norfolk, Excavations at, 522.

HARMER, F. W., Pliocene Mollusca, Great Britain, 565.
Haselhurst, S. R., Cone-in-Cone Structure, 92.
Haward, F. N., Early Man, 573.
Hay, O. P., Extinct Sirenian, 567.
Hercolepas, gen. nov., T. H. Withers, 117.
Hickling, G., *Parka dicipiens*, 284.
Hill, E., Coast Erosion, Norfolk, 476.
Hind, Wheelton, Millstone Grit Fauna, 88.
Hinxman, L. W., Geology of Strathspey, 281.
Hobson, B., Underground Flow, Yorkshire Dee, 383; Bursting of Lake Barrier, 576.
Holmes, A., Radio-activity, 60, 102; Petrology, North-West Angola, 228, 322, 367.
Holmes, T. V., Cumberland by Solway, Geological Structure of, 410.
Holst, N. O., Ice Age, England, 418, 434, 504.
Horne, J., Geology of Beauly and Inverness, 330.
Howe, J. A., Kaolin, China Clay, etc., in Jermyn Street Museum, 371.
Hughes, T. McKenny, Shippea Hill Man, 44; Gravels of East Anglia, 137.
Hull Museum, Middlemiss Collection presented to, 288.
Human Palæontology, England, 476.
—— Remains and Implements, England, 429.
Hunt, A. R., Obituary of, 96, 140.
Hydraulic Limestone, Fauna of, 150.

ICE Age, England, 418, 434, 504.
Iddings, G. P., Problem of Volcanism, 331.
Igneous Rocks and Carboniferous Limestone, Bristol, 284.
Implements, Early Man, 573.
Indian Geological Terminology, 89.
Intrusions, Penmaenmawr, 15.
Intrusive Rock, Marston Jabet, Warwick, 152.

JOHNSTON, M. S., *Labechia rotunda*, 433.
Jones, O. T., Geology round Machynlleth, 93.

Jowett, A., Glacial Geology, South Pennines, 468.
Jurassic Brachiopoda, 380.

KAOLIN, China Clay, etc., Handbook Mus. Prac. Geol., 371.
Kennard, A. S., Late Glacial Mollusca Lea Valley, 282.
Kent Coal-field, 567.
Kew, W. S. W., Tertiary Echinoids, California, 375.

LABECHIA rotunda, sp. nov., M. S. Johnston, 433.
Lacroix, Laterites of French Guinea, 28, 77, 123.
Lake, P., Physical Geography, 277.
Lake Basins and Moraine Walls, North Italy, 403.
Lakes in Switzerland, 343.
Lang, W. D., Cretaceous Cheilostome Polyzoa, 496.
Laterite, 286.
—— in French Guinea, 28, 77, 123.
—— in Guiana, 47.
Leeds Geological Association, 379.
Limestone, Origin of, 158.
Liverpool Geological Society, 88, 96, 572.
Long Island, Geology of, 42.
Lonsdaleia and *Dibunophyllum*, 188.
Lower Carboniferous Rocks and Coal-measures, Somerset, 312.
Lower Tertiary Marine Rocks, Australia, 328.
Lydekker, R., Obituary Notice of, 238.

MACHYNLLETH and Llyfnant, Geology of, 93.
MacKenzie, J. D., Crowsnest Volcanics, 84.
Man, Early, 573.
Marble District of Carrara, Massa, Versilia, 289, 554.
Marine Band, Coal-measures, South Lancashire, 311.
Marr, J. E., Ashgillian Succession, West Coniston, 187.
Marston Jabet, Intrusive Rock of, 152.
Marsupites Chalk, Brighton, 12.
Maufe, H. B., Coastal Series of Sediments, East Africa, 274.
Medina and Cataract Formations, New York and Ontario, 378.
Mennell, F. P., Rocks of Lyd Valley, Dartmoor, 334.
Merrick, E., Tyne Drainage Area, 294, 353.
Mesozoic Plants, Natural History Museum Catalogue, 474.
Meteoric Irons from Klondyke, 476.
Metriorhynchus, Fore-paddle, Oxford Clay, Peterborough, 444.
Mid-Strathspey and Strathdearn, Geology of, 281.
Millett, F. W., Obituary Notice of, 288.
Mineral Resources of United States, 38.
—— Waters and Radio-activity, 179.
Mineralogical Society, 139, 236, 382.
Minerals and Rocks, Useful, Origin and Form, 177.
—— of United States, 136.
Mining Districts, Montana, U.S., 89.
—— Operations, South Australia, 431.
Moine Pebbles, Torridonian Conglomerates, 447.
Moir, J. R., Pre-Palæolithic Flint Implements, 46; Flints from Suffolk Bone Bed, 191; Human Palæontology, 476.
Mollusca in Opal Deposits, New South Wales, 425.
—— Late Glacial, of Lea Valley, 282.
—— Marine Miocene, California, 90.
Molluscan Deposits of Wexford and Manxland, 164.
Moorcroft Oil-field, Wyoming, U.S., 427.
Moraine Walls and Lake Basins, North Italy, 403.
Morse, E. S., Early Stage of *Acmæa*, 41.
Mueller, F. P., Tektite from British Borneo, 206.
Myotragus balearicus, Skeleton of, 338.
Myrmecoboides montanensis, Gidley, 430.
Mystriopora möckleri, gen. et sp. nov., W. D. Lang, 502.

NATURAL History Museum, Catalogue of Books, 432.
Neorhynchia, gen. nov., J. A. Thomson, 388.
New South Wales, Geology of, 134.
New Zealand, Brachiopods, 71, 387, 461, 570.
—— Mollusca, 570.
Newall, R. S., Guide to Fossil Remains of Man, 191.
Newton, R. B., Age of Australian Tertiaries, 328; Mollusca in Opal, New South Wales, 425.

Norfolk and Norwich Naturalists, 88.
North, F. J., Silurian Inlier, Cardiff, 386.
North American Geology, 378.
Norwich Castle Museum, Report of, 88.

OBITUARY Notices : Anderson, W., 478 ; Callaway, C., 525 ; Geikie, J., 192 ; Hunt, A. R., 96, 140 ; Lydekker, R., 238 ; Millett, F. W., 288 ; Rudler, F. W., 142.
Oil- and Gas-fields, Kentucky, Papua, Wyoming, 427.
—— —— Olympic Peninsula, Washington, U.S., 428.
Oil-shales of Colorado and Utah, 428.
Old Red Sandstone, Kiltorcan, Ireland, 469.
Oligocene Mollusca, Silex Beds, Florida, 428.
Oolite from Bethlehem, Pa., U.S., Peculiar, 568.
Ophthalmosaurus icenicus, Mounted Skeleton, 145.
Ore-deposits, North-East Washington, 137.
Origin of Limestone, 158.
Ottawa, Report of Geological Survey of, 136.
Oxford Clay Plesiosaur, New, 341.

PABLO (San) Fauna, California, 569.
Paisley Abbey, Excavations at, 88.
Palæolithic Age and Climate, Egypt, 90.
Palæontographical Society Volume for 1914, 565.
Palæozoic Fossils referred to Cirripedia, 112.
—— Stelleroidea, U.S., 425.
Parka decipiens, Fleming, 284.
Pascoe, E. H., Petroleum of Assam and Bengal, 377.
Peldar Tor and High Sharpley, 545.
Penmaenmawr Intrusions, 15.
Permo-Triassic Sequence in Solway Basin, 241.
—— Rocks, Cumberland by Solway, 410.
Perret, F. A., Recent Eruption of Stromboli, 134.
Petrie, W. M. Flinders, Palæolithic Age, Egypt, 90.
Petrography, Saturation in, 339.
Petroleum of Assam and Bengal, 377.
—— in Papua, 427.
Petrology, North-Western Angola, 228, 267, 322, 367.
Petrology of Suffolk Box-stones, 250.
Phosphate Deposits, Idaho, 378.
Physical Geography, 277.
Pitchstones of Mull and their Genesis, 138.
Plants of Glacial Deposits, Lea Valley, 188.
Plesiosaur from Oxford Clay, New, 341.
Pliocene Mollusca, Great Britain, 565.
Polar Climates, 450.
Polyzoa, New Cretaceous Cheilostome, 496.
Ponder's End Stage of Lea Valley, 282.
Portuguese East Africa, 179.
Post-Cretaceous Alkaline Rocks, Loanda, 322.
Potash in Texas Permian, 378.
Preller, C. S. Du Riche, Zonal Lake Basins, 215 ; Swiss Lakes, 343 ; Moraine Walls and Lake Basins, Italy, 403 ; Carrara, Massa, etc., Marble Districts, 554.
Pre-Palæolithic Flint Implements, 46.
Principle of Saturation, 160.
Pyrgocystis, gen. nov., F. A. Bather, 5.
—— *Ansticei*, n.sp., F. A. Bather, 49.
—— *Grayæ*, n.sp., F. A. Bather, 10.
—— *Sardesoni*, n.sp., F. A. Bather, 6.

RADIO-ACTIVE Methods determining Geological Time, 187.
Radio-activity and Earth's Thermal History, 60, 102, 273.
Rastall, R. H., Minerals of Lake District Granites, 334 ; Andalusite and Chiastolite, 336.
Raymond, P. E., *Cryptophragmus*, 85.
Reid, C., Plants of Glacial Deposits, Lea Valley, 188.
Reptiles and Batrachians, 38.
Reynolds, S. H., Igneous Rocks, Bristol District, 284.
Rhammatopora, gen. nov., W. D. Lang, 496.
—— *Pembrokiæ*, sp. nov., W. D. Lang, 499.
—— *Vinei*, gen. et sp. nov., W. D. Lang, 498.
Rhodesia Museum, Department of Geology, 378.
Rhynchonellids, Recent and Tertiary, 387.
Rocks of Lyd Valley, Dartmoor, 334.
Royal Society, Canada, 432.
Rudler, F. W., Obituary of, 142.

Rugby School Natural History Society, 88.

SARGENT, H. C., Penmaenmawr Intrusions, 15.
Saturation, Principle of, 160.
—— in Petrography, 339.
Schlotheimia Greenoughi, J. Sowerby, sp., 97.
Schuchert, C., Paleozoic Stelleroidea, U.S., 425.
Scott, A., Principle of Saturation, 160; Crawfordjohn Essexite, 455, 513.
Scrivenor, J. B., Laterite, 286.
Seascale, Cumberland, Deep Bore at, 146.
Secondary and Tertiary Periods, Limits of, 87.
Shand, S. J., Saturation in Petrography, 339; Alkaline Rocks S.W. Africa, 575.
Shelton, H. S., Methods of determining Geological Time, 187.
Sherlock, R. L., Marine Band, Coal-measures, S. Lancs, 311.
Shippea Hill Man, Age and Character, 44.
Silurian Inlier, Usk (Monmouth), 91; Cardiff, 386.
Smellie, W. R., New Plesiosaur, Oxford Clay, 341.
Smith, S., *Lonsdaleia* and *Dibunophyllum*, 188.
Smith, J. P., Invertebrate Fauna, North America, 39.
Solway Basin, its Permo-Triassic Sequence, 241.
South Wales Coalfield, Geology of, 171.
Spath, L. F., on *Schlotheimia Greenoughi*. 97.
Spiti Shales, Fauna of, 40.
Stegosaurus, New Restoration of, 525.
Stopes, C. M., Catalogue of Mesozoic Plants, 474.
Strahan, Aubrey, Geology of South Wales Coalfield, 171.
—— Notice of, 193.
Stratigraphy and Petrography of London Basin, 234.
Stromatoporoid, New, Wenlock Limestone, Shropshire, 433.
Stromboli, Recent Eruption of, 134.
Supposed Oil-bearing Areas, South Australia, 428.
Süssmilch, Geology of New South Wales, 134.
Suter, H., Tertiary Mollusca, New Zealand, 374, 570.
Swinnerton, H. H., Classification of Trilobites, 487, 538.
Switzerland, Zonal Lake Basins of, 215.

TARR, R. S., Physiography, 82.
Taylor, R. Cowling, Norfolk Geologist, 88.
Tektite from British Borneo, 206.
Temperature in Deep Boring, Ohio, 42.
Terebratulacea, Types of Folding in, 71.
Tertiary Echinoids, San Pablo, California, 375.
—— Mollusca, New Zealand, 374, 570.
Thecidellina, gen. nov., J. Allan Thomson, 461; *Th. hedleyi*, sp. nov., J. Allan Thomson, 461.
Thecidiinæ, New Genus of, 461.
Thomson, J. A., Brachiopod Morphology, 71; Recent and Tertiary Rhynchonellids, 387; New Genus of Thecidiinæ, 461; Brachiopod Genera, 570.
Torridon Sandstone and Moine Gneiss, 447.
Transportation of Debris by Water, 42, 132.
Trematosaurus Sobeyi, Haughton, 430.
Triassic Marine Invertebrates, North America, 39.
Trilobites, Classification of, 487, 538.
Trueman, A. E., Fauna of Hydraulic Limestone, 150.
Twenhofel, W. H., Anticosti Island Faunas, 84.
Tyne Drainage Area, 294, 353.
Tyrrell, G. W., Bekinkinite of Barshaw, 304, 361.

UNDERGROUND Flow, Yorkshire Dee, 383.

VICTORIAN Meteorites, 475.
Volcanics of Crowsnest, 84.
Volcanism, Problem of, 331.

WARREN, S. H., Ponder's End Stage of Lea Valley, 282.
Warth, H., Origin of Limestone, 158.
Water of Volcanoes, 175.

Water Reptiles, Past and Present, 37.
Watson, T. L., Engineering Geology, 85.
Watts, W. W., Life of, 481.
Wewoka Formation, Oklahoma, 569.
Wexford and Manxland, Molluscan Deposits of, 164.
Wherry, E. T., Oolite, Bethlehem, 568.
Williston, S. W., Water Reptiles, 37.
Wilmore, A., Carboniferous Zones, Lancs, 521.
Winchell, A. N., Mining Districts, Montana, 89.
Windsor and Chertsey, Geology of, 232.
Winwood, H. H., Geological Age of Carrara Marbles, 289.
Withers, T. H., Palæozoic Fossils referred to Cirripedia, 112.
Wood, S. V., Mollusca, 565.
Woodward, A. S., Bone Implement, Piltdown, 45; Guide to Fossil Remains of Man, 129; Presidential Address to Geological Society, 186.
—— Eminent Living Geologist, 1.
Woodward, B. B., Late Glacial Mollusca, Lea Valley, 282.
Woodward, B. H., Retirement from Museum, Perth, W.A., 192.

ZEALAND, New, Brachiopod Shells, 570.
Zonal Lake Basins, Switzerland, 215.
Zones of Chalk, Middlesex and East Bucks, 238.
Zoological Society, London, 43, 286, 335.

DEC 21 1915

No. 618. Decade VI.—Vol. II.—No. XII. Price 2s. net.

THE GEOLOGICAL MAGAZINE

OR

Monthly Journal of Geology.

WITH WHICH IS INCORPORATED

THE GEOLOGIST.

EDITED BY

HENRY WOODWARD, LL.D., F.R.S., F.G.S., &c.

ASSISTED BY

PROFESSOR J. W. GREGORY, D.Sc., F.R.S., F.G.S.
DR. GEORGE J. HINDE, F.R.S., F.G.S.
SIR THOMAS H. HOLLAND, K.C.I.E., A.R.C.S., D.Sc., F.R.S., F.G.S.
DR. JOHN EDWARD MARR, M.A., Sc.D. (CAMB.), F.R.S., F.G.S.
DR. J. J. H. TEALL, M.A., Sc.D. (CAMB.), LL.D., F.R.S., F.G.S.
PROFESSOR W. W. WATTS, Sc.D., M.Sc., F.R.S., [illegible] GEOL. SOC.
DR. ARTHUR SMITH WOODWARD, F.R.S., F.L.S., PRES. GEOL. SOC.

LIBRARY OF THE
UNIVERSITY OF WISCONSIN
MADISON

DECEMBER, 1915.

CONTENTS.

I. ORIGINAL ARTICLES. *Page*

The Danbury Gravels. By Professor J. W. GREGORY, D.Sc., F.R.S. ... 529

A Revised Classification of Trilobites. By Professor H. H. SWINNERTON, D.Sc., F.G.S. (With 6 Text-figures.) (*Concluded.*) ... 538

The North-Western Region of Charnwood Forest. By Professor T. G. BONNEY, Sc.D., LL.D., F.R.S. ... 545

The Carrara, Massa, and Versilia Marble District. By C. S. DU RICHE PRELLER, M.A., Ph.D., F.G.S., F.R.S.E. (With 6 Text-figures.) ... 554

II. REVIEWS.

The Pliocene Mollusca of Great Britain. By F. W. Harmer, F.G.S. ... 565

The Sub-Crag Detritus-Bed. By A. Bell ... 566

REVIEWS (*continued*). *Page*

The Extinct Sirenian *Desmostylus hesperus*, Marsh. By O. P. Hay 567

Herbert Bolton's Fauna of the Kent Coal-field ... 567

Oolite from Bethlehem, Pa., U.S. By Edgar T. Wherry ... 568

Fauna of Wewoka, Oklahoma. By G. H. Girty ... 569

Fauna of San Pablo Group, California. By Bruce L. Clark ... 569

Brachiopod Genera. By J. Allan Thomson ... 570

Tertiary Mollusca, New Zealand. By Henry Suter ... 570

III. REPORTS AND PROCEEDINGS.

Geological Society of Glasgow ... 571

Liverpool Geological Society ... 572

Geological Society of London ... 573

IV. CORRESPONDENCE.

F. N. Haward ... 573

M. l'Abbé Breuil ... 574

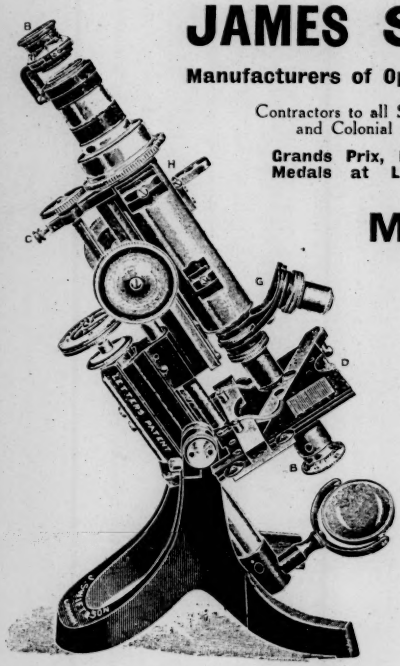
Professor S. J. Shand ... 575

Bernard Hobson ... 576

With this Number is presented an Extra Sheet, containing Index, Title-page, etc., for Decade VI, Vol. II, 1915.

LONDON: DULAU & CO., LTD., 37 SOHO SQUARE, W.

☞ The Volume for 1915 of the GEOLOGICAL MAGAZINE is ready, price 26s. net. Cloth Cases for Binding may be had, price 1s. 6d. net.



JAMES SWIFT & SON,

Manufacturers of Optical and Scientific Instruments,

Contractors to all Scientific Departments of H.M. Home and Colonial and many Foreign Governments.

Grands Prix, Diplomas of Honour, and Gold Medals at London, Paris, Brussels, etc.

MICROSCOPES

AND OTHER

INSTRUMENTS FOR

ALL BRANCHES OF

GEOLOGY, MINERALOGY, PETROLOGY.

Sole Makers of the
"DICK" MINERALOGICAL MICROSCOPES.
Dr. A. HUTCHINSON'S UNIVERSAL GONIOMETER.

University Optical Works,
81 TOTTENHAM COURT ROAD,
LONDON.

PRICE 15s. NET. IN TWO SHEETS.

A GEOLOGICAL MAP OF THE CAUCASUS

(WITH EXPLANATORY TEXT).

Compiled from the latest sources by FELIX OSWALD, D.Sc., F.G.S.

Scale 1 : 1,000,000 (15·78 miles = 1 inch). The geological formations and the igneous rocks are clearly displayed in twenty different colours. The glaciers are also indicated. All heights are given in English feet, and the latest railways have been inserted. The pamphlet of explanatory text gives a brief account of the main physical divisions of the Caucasus, followed by a detailed description of the successive geological horizons with their characteristic fossils. Special care has been taken to indicate the exact position in the geological series at which petroleum occurs in the Caucasian oil-fields.

"It is produced in a bold style, somewhat like that of Noë's Map of the Alps, and embodies a good deal of personal study by the author. This work will be of service to many travellers, now that the district is so accessible through Constantinople or Odessa, and it will be of much help to readers of Suess's description of the range."—*Nature* (August 30, 1914).

DULAU & CO., Ltd., 37 Soho Square, London, W.

LIST OF BOOKS OFFERED FOR SALE

AT THE NET PRICES AFFIXED BY

DULAU & CO., LTD., 37 SOHO SQUARE, LONDON, W.

CHAPMAN (F.). Australasian Fossils: a Students' Manual of Palæontology. With an Introduction by Professor E. W. Skeats, D.Sc., F.G.S. Crown 8vo. pp. 341, with 150 illustrations and Map of Australia. 7*s.* 6*d.*

GEOLOGICAL MAGAZINE.—The work cannot fail to be of great service, not only to students, but to all interested in geological studies on the other side of the globe.

CRAIG (E. H. C.). Oil Finding: an Introduction to the Geological Study of Petroleum. 2nd ed. London, 1914. 8vo. pp. 208. Cloth. 8*s.* 6*d.*

CRAMPTON (C. B.) AND CARRUTHERS (R. G.). The Geology of Caithness. Edinburgh (Geol. Surv.), 1914. 8vo. Illustrated. 4*s.*

DUNN (E. J.). Pebbles. Melbourne [1911]. 8vo. pp. 122, with 76 plates, illustrating 250 figures. Cloth. 15*s.*

More than half a century has been spent in acquiring, in different countries, the material necessary for the illustrations, and it is hoped that they will prove useful to students of Geology and of Nature generally.

ECKEL (E. C.). Iron Ores: their occurrence, valuation, and control. New York, 1914. 8vo. Illustrated. Cloth. 17*s.*

FINLAY (G. I.). Introduction to the Study of Igneous Rocks. London, 1913. Crown 8vo. pp. 228, with 3 coloured plates and numerous illustrations. Flexible leather. 8*s.* 6*d.*

GOLDFUSS (G. A.). Petrafacta Germaniæ. Abbildungen und Beschreibungen der Petrefacten Deutschlands und der Angrenzenden Länder. Herausgegeben von Dr. A. Goldfuss. Dusseldorf, 1826–4. 3 vols. of text and 3 vols. of plates, 6 vols. in 4. 700 pp. of letterpress; 201 plates, comprising a vast number of illustrations. Folio. Half-morocco. £7 10*s.*

GREGORY (J. W.). Geology of To-day. A popular introduction in simple language. London, 1915. 8vo. pp. 328, with 24 plates and illustrations. Cloth. 5*s.*

GUPPY (H. B.). Observations of a Naturalist in the Pacific between 1896 and 1899. Vol. I: Vanua Levu, Fiji, a description of its leading Physical and Geological Characters. Vol. II: Plant-Dispersal. London, 1903–10. 2 vols. 8vo. Illustrated. Cloth (36*s.*). 15*s.*

HUTCHINSON (H. G.). Life of Sir John Lubbock (Lord Avebury). London, 1914. 2 vols. 8vo. pp. 352, 344. £1 10*s.*

IDDINGS (J.). The Problems of Volcanism. (Silliman Memorial Lectures.) New Haven, 1914. Roy. 8vo. With 86 illustrations and chart. Cloth. £1 1*s.*

JOHANSSEN (A.). Manual of Petrographic Methods. New York, 1914. 8vo. Illustrated. Cloth. £1 5*s.*

JOLY (J.). The Birth-time of the World, and other scientific essays. London, 1915. 8vo. With 28 plates and 15 illustrations in text. Cloth. 10*s.* 6*d.*

KEITH (A.). The Antiquity of Man. London, 1915. 8vo. With 189 illustrations. Cloth. 10*s.* 6*d.*

KEMP (J. F.). Handbook of Rocks for use without the microscope, with a glossary of the names of rocks. 5th ed. rev. New York, 1911. 8vo. Illustrated. Cloth. 7*s.* 6*d.*

—— The Ore Deposits of the United States and Canada. New York, 1906. 8vo. Illustrated. Cloth. £1 1*s.*

LAKE (P.). Physical Geography. Cambridge, 1915. 8vo. With 20 plates. Cloth. 7*s.* 6*d.*

LIST OF BOOKS OFFERED FOR SALE

AT THE NET PRICES AFFIXED BY

DULAU & CO., LTD., 37 SOHO SQUARE, LONDON, W.

LANKESTER (Sir RAY). Diversions of a Naturalist. London, 1915. 8vo. With coloured front and 43 other illustrations. Cloth. 6*s*.

LECONT (J.). Elements of Geology. 5th ed., revised and enlarged. With new plates and illustrations. New York, 1915. 8vo. Cloth. 18*s*.

LEITH (C. K.). Structural Geology. London, 1914. 8vo. pp. 169, with 68 text-illustrations. Cloth. 6*s*. 6*d*.

Its purpose is the study and interpretation of rock-structures, not for themselves, but for the light they may throw on stratigraphic problems, on economic geology, on the causes underlying the general configuration of the earth, and on the earth's history.

LEVY (O. I.). The Rare Earths, their Occurrence, Chemistry, and Technology. London, 1914. 8vo. pp. 360. Cloth. 10*s*. 6*d*.

MARR (J. E.). The Scientific Study of Scenery. 4th edition. London, 1912. 8vo. pp. 372, with 23 plates and illustrations. Cloth. 5*s*.

PRIMROSE (J. S. G.). The Practical Metallography of Iron and Steel. London, 1913. 8vo. pp. 130. Sewed. 3*s*.

RICHARDSON (C. H.). Economic Geology. New York, 1913. 8vo. pp. 320, with many illustrations. Cloth. 10*s*. 6*d*.

CONTENTS.—Ore Deposits.—Origin of Ore Deposits.—Precious Metals.—Gold, Silver, Platinum.—Useful Metals.—Rare Metals.—Economics.

SEWARD (A. C.). Antarctic Fossil Plants of the *Terra Nova* Expedition, 1910. London, 1914. 4to. pp. 49, with 8 plates, 3 maps, and text-figures. 6*s*.

SHIMER (H. W.). Introduction to the Study of Fossils, Plants, and Animals. New York, 1914. Crown 8vo. Illustrated. Cloth. 10*s*. 6*d*.

SOLLAS (W. J.). Ancient Hunters and their modern representatives. 2nd ed. London, 1915. pp. 591. 8vo. With 2 plates and 314 illustrations in the text. Cloth. 15*s*.

CONTENTS.—The Great Ice Age—The Antiquity of Man—Eoliths—Extinct Hunters—Middle Palæolithic—The Aurignacian Age—The Solutrian Age.

WILLIS (B.) and others. Outlines of Geologic History, with especial reference to North America. Edited by R. D. Salisbury. Chicago, 1910. 8vo. Illustrated. Cloth. 6*s*.

All Communications for this Magazine should be addressed to

THE EDITOR,

13 Arundel Gardens, Notting Hill, London, W.

Books and Specimens to be addressed to the Editor as usual, care of

MESSRS. DULAU & CO., LTD., 37 SOHO SQUARE, W.

STEPHEN AUSTIN AND SONS, LTD., PRINTERS, HERTFORD.